Compressors, and Brake Equipments

By

I.C.S. STAFF

AIR-BRAKE COMPRESSORS
A-1 ENGINE EQUIPMENT

514 B

Published by
INTERNATIONAL TEXTBOOK COMPANY
SCRANTON, PA.

INTERNATIONAL TEXTBOOK PRESS
Scranton, Pa.

84387

CONTENTS

NOTE.—This book is made up of separate parts, or sections, as indicated by their titles, and the page numbers of each usually begin with 1. In this list of contents the titles of the parts are given in the order in which they appear in the book, and under each title is a full synopsis of the subjects treated.

AIR-BRAKE COMPRESSORS

A-1 ENGINE EQUIPMENT

KEY TO THE COLOR PLATES

RED	*Main-Reservoir Pressure*
PINK	*Brake-Cylinder Pressure*
GREEN	*Auxiliary-Reservoir Pressure*
BLUE GREEN	*Feed-Valve-Pipe Pressure*
LIGHT GREEN	*Equalizing-Reservoir Pressure*
ORANGE	*Atmospheric Pressure*
YELLOW	*Brake-Pipe Pressure*
BLUE	*Live Steam*
LIGHT BLUE	*Exhaust Steam*
PURPLE	*Application-Chamber Pressure* *Supplementary-Reservoir Pressure*
GRAY	*Feed-Valve-Pipe Pressure*
BROWN	*Low-Pressure Air-Cylinder Pressure*
LAVENDER	*Signal-Pipe Pressure*

AIR-BRAKE COMPRESSORS

Serial 1957 Edition 2

INTRODUCTION AND DEVELOPMENT OF THE AIR BRAKE

HISTORICAL

1. Introduction.—In the year 1866 Mr. George Westinghouse was a passenger on a train running between Schenectady and Troy, N. Y. During the trip the train was delayed several hours on account of a collision between two freight trains, and it occurred to him then that the accident could have been avoided had the engine crews some means of applying brakes at the same time to all the wheels of the cars comprising their trains. His first idea toward accomplishing this result was to connect the brake levers of each car to its draft gear and rely on the closing up of the cars toward the locomotive when steam was shut off on the engine to apply the brakes through the couplers and levers with sufficient force to bring the train to a stop. It next occurred to him to employ steam for the operating pressure in the development of a power brake, but this idea was also abandoned as impracticable.

2. Mr. Westinghouse in an address delivered before the American Society of Mechanical Engineers at Pittsburgh, Dec. 6, 1910, told how he obtained the idea of using compressed air to operate a brake. He said that, during the time he was considering a suitable agency to employ to operate a power brake, he was induced to subscribe to a monthly publi-

cation, and in about the first issue he noticed an account of the tunnel that was then being driven through Mt. Cenis in the Alps. It was explained that the tunneling machinery was driven by compressed air conveyed through 3,000 feet of pipe. He then designed an apparatus in which compressed air was employed to force brake shoes against the wheels of the cars, and secured a patent on the device in 1867. Its manufacture led to the formation of the Westinghouse Air Brake Company in 1869.

3. The Straight Air Brake.—The essential parts of the first power brake operated by compressed air were as follows: An air compressor driven by a steam engine receiving its supply from the boiler of the locomotive, a main reservoir on the locomotive into which air was compressed to about 60 or 70 pounds pressure per square inch, a pipe leading from the reservoir to a valve mechanism convenient to the engineer, brake cylinders for the tender and each car, a line of pipe leading from the brake valve under the tender and all of the cars with a branch pipe connection to each brake cylinder, the brake pipe being connected between each car by flexible hose. The device was known as a *straight air brake,* the brake being applied by allowing air stored in the main reservoir to pass through the brake pipe to the brake cylinders when the operating valve was moved to the proper position. The brake was released by moving the operating valve to a position to exhaust the air from the brake cylinders back through the brake pipe to the atmosphere.

4. Automatic Brake With Plain Triple Valve. The evident disadvantages of this equipment, especially in the case of a break-in-two, a common occurrence in those days, caused further research, that led in 1872 and 1873 to the introduction of two additional parts, namely, an auxiliary reservoir and a plain triple valve. The braking pressure for each car was carried in the auxiliary reservoir on that car instead of in one reservoir on the locomotive, and the brake was applied by decreasing the pressure in the brake pipe, and released by increasing the pressure in the brake pipe, the change in pres-

sures affecting the triple valve, causing it to transfer air from the auxiliary reservoir to the brake cylinder in the first case, and from the brake cylinder to the atmosphere in the latter case, or when releasing the brake. The movement of the air when applying and releasing the brakes with the plain automatic brake was then in the reverse direction to its movement during the operation of the straight air brake. The brake was said to be automatic in action, as the brakes would apply were the brake-pipe pressure materially decreased from any cause, either at the will of the engineer, by hose bursting, or by a break-in-two. It is worthy of note that the combination of brake cylinder, auxiliary reservoir, and triple valve evolved at this time still remains a part of the air-brake system, and it has been commented on as being remarkable that through all subsequent improvements not one of the original functions of the triple valve has been discarded, but that they have been extended and many new functions added.

The principal objection to the plain automatic brake was its slow response during emergency applications with long trains, due to the fact that all the brake-pipe air was exhausted through the brake valve, and the fall in pressure was comparatively slow on account of the friction encountered by the air in its passage through the brake pipe.

5. Automatic Brake With Quick-Action Triple Valve.—In 1887, as a result of the Burlington, Iowa, tests, an additional or quick-action feature was added to the plain triple valve which overcame the disadvantages of the automatic brake equipped with plain triple valves. In other respects both brakes were similar. The action of the added parts was such that when a quick heavy reduction in brake-pipe pressure was made at the brake valve or otherwise, the triple valve, in addition to connecting the auxiliary reservoir to the brake cylinder, opened a direct communication from the brake pipe to the brake cylinder, and the brake was said to apply quick action. The sudden decrease in brake-pipe pressure caused the next triple valve to apply in quick action, and this valve in turn operated the next in a like manner, thus transmitting

the quick action serially from triple valve to triple valve in a very short time. The delay in the exhausting of air from the brake pipe due to friction was thus avoided as the air was short-circuited, as it were, to the brake cylinders, the result being a very rapid application of the brakes. This valve is commonly known as the type H quick-action triple valve.

6. Quick-Action Automatic Brake With K Triple Valve.—The type H triple valve functioned satisfactorily during service applications on trains of medium length, but as the length of freight trains increased, it was found that the brakes applied too slowly in service applications, the time interval between the application of the front and rear brakes being too long, resulting in heavy shocks. This triple valve then had the same defect during service applications as the plain triple had during emergency applications, the slowness of the reduction being due to the causes already explained, or to the friction encountered by the brake-pipe air, which during service applications escaped at the brake valve only. Additional features were then added to the type H valve, which in 1903 resulted in the introduction of a triple for freight service only, and known as the type K triple valve. This valve caused a quicker service application of the brakes on long trains in addition to other important features; the quick-service feature resulted from the fact that each triple valve caused a light local reduction in brake-pipe pressure by venting the air to the brake cylinders, the action being similar in principle to that brought about by the addition of the quick-action parts to the plain triple in emergency, but less severe. The local reduction, being light, does not produce emergency action but merely accelerates service action.

Until the introduction of the K triple valve, the difference between freight and passenger equipment was largely one of auxiliary reservoirs and brake cylinders of greater volume, no material change being made in the operating parts with the exception of the application of reducing valves to passenger brake cylinders. However, since that time various equipments exclusively for passenger service have been introduced,

designed to meet conditions brought about by the introduction of the modern all-steel passenger coach.

7. Present-Day Equipments.—The air-brake equipments in use at the present time are divided into those designed for locomotives, and equipments for freight and passenger cars. Equipments are given in the order of their introduction.

The locomotive equipments in general use are the A-1 equipment; the combined automatic and straight air-brake equipment, which consists of the A-1 equipment and the additional parts necessary for a straight air brake, these parts for the engine being known as schedule SWA and for the tender as schedule SWB; the No. 6 ET locomotive brake equipment, and the No. 8 ET locomotive brake equipment, the letters ET standing for engine and tender. The No. 8 ET locomotive brake equipment operates on the same basic principle as employed in the No. 6 ET locomotive brake equipment but the No. 8 ET equipment provides numerous new functions and features.

There are two freight brake equipments in use, namely the type K freight brake equipment and the AB freight brake equipment. The principle changes responsible for the introduction of the AB freight brake equipment were higher speeds, faster schedules, longer trains, and heavier cars, all of which tended to render the type K freight brake equipment less satisfactory and efficient.

8. There are four brake equipments for passenger cars in general use: The high-speed brake, now generally known as the PM equipment, so named because the type P triple valve and type M brake cylinder are used; the LN equipment, also named from the type of triple valve and brake cylinder used; the PC and UC equipment, the letters PC and UC being abbreviations for passenger control and universal control. As the name implies, the latter equipment is designed for any class of passenger service, and with that end in view it is so constructed that additional parts can be added to it as desired, which will give it the new feature necessary to meet successfully a change in conditions requiring a brake of greater power and flexibility. It is known as the universal pneumatic

equipment, schedule UC. In its most refined form the operation of the universal valve, which corresponds in a general way to a triple valve, is controlled by magnet valves that are operated by an electric current, when the necessary contacts are made by the engineer's brake valve. As the opening and closing of the magnet valves are simultaneous, a uniform application and release of all brakes is assured regardless of the length of the train. With the electric features added, this brake becomes an electric pneumatic equipment.

AIR-BRAKE INSTRUCTION

9. Introductory Study.—The method formerly followed when beginning the study of the air brake was to consider the different parts comprising the apparatus separately, the location and relation of the different chambers and passages in each part being learned, as well as the different connections that were made according to the different positions of the moving parts. While a knowledge of the detailed operation of the parts is of value in its proper place, yet it should form no part of an introduction to the study of air brakes. When individual parts of the apparatus are considered separately, the relation existing between the parts when operating together as a whole, as well as the principles on which their operation depends, are frequently lost sight of. Preliminary air-brake instruction should then consist (1) of a study of the underlying principles of operation; (2) the names and arrangement of the parts of a complete air-brake unit; (3) the application of the above principles to the general operation of an air-brake unit. Having acquired such preliminary knowledge at the outset, the purpose and functions of the various brake mechanisms can be easily understood, as the principles laid down will be found to be applicable to all.

10. Principles of Brake Operation.—The operation of the air brake is due to that property possessed by air under compression of returning to atmospheric pressure if permitted, or of tending toward equality of pressure throughout any

closed system after a previous balance of pressure has been destroyed. When the brake system is charged with compressed air and is then temporarily opened to the atmosphere, the tendency of the air in a part of the system to return to atmospheric pressure causes the air to expand from the former to the latter, and the pressure in other parts of the system now being unbalanced, will endeavor to reestablish the equality existing throughout the system prior to its being opened. Closing off the brake system to the atmosphere and connecting it to a source of higher pressure will also result in an inequality of pressure and the tendency will again be toward a restoration of a balance of pressure. The parts of the brake apparatus are so arranged that their movement when affected by a variation of pressure will result in a distribution of compressed air that brings about the operation of the brakes.

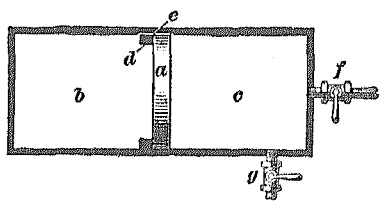


FIG. 1

11. The tendency for pressures after being unbalanced to again become balanced can be more readily understood by considering Fig. 1. In Fig. 1 the piston *a* separates chamber *b* from chamber *c*. When the piston is up against the ring *d*, the two chambers are connected through a small groove *e* cut in the wall of the cylinder and ring *d*, but in all other positions the piston is assumed to work air-tight in the cylinder with little friction. Pipe and cock *f* lead to a source of higher pressure, and when the cock is opened for a short time the air will enter chamber *c* and passing through groove *e* will charge chamber *b*, the pressures in the two chambers finally becoming equal. Opening cock *g* to the atmosphere slowly for an instant gradually reduces the pressure in chamber *c* below that in chamber *b*, and therefore unbalances the two pressures, it being assumed that the air is being reduced in chamber *c* faster than it can pass through groove *e*. The air in chamber *b* in its attempt to become equal to that in chamber *c* immediately begins to move piston *a* to the right; or, as gen-

erally stated, the piston is moved by the higher pressure in chamber *b* toward the lower pressure in chamber *c*. The movement of piston *a* continues until the air in chamber *b* expands and its pressure becomes balanced or equal to that in chamber *c*, after which the movement stops. If after cock *g* is closed cock *f* is again opened, the piston will be moved to its original position by the greater pressure in chamber *c* acting in opposition to the lesser pressure in chamber *b*.

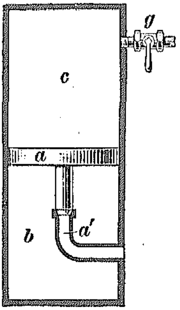


FIG. 2

12. Fig. 2 shows that the effect of pressures balancing after being unbalanced can be employed in connection with the proper arrangement of parts to open and close a port. In Fig. 2, piston *a* has a stem normally seating in the inner end of passage *a′* which is open to the atmosphere at the other end. Assume that the pressure in chambers *b* and *c* are equal and that cock *g*, which connects chamber *c* to the atmosphere when open, is slowly opened for an instant and then closed. The pressures on each side of piston *a* are now unbalanced and the air in chamber *b*, in an endeavor to reestablish a balance of pressure with the air in chamber *c* moves piston *a* upwards away from the greater pressure in chamber *b* toward the lesser pressure in chamber *c*. However, as soon as piston *a* moves upwards, its stem opens passage *a′* and the pressure in chamber *b* begins to escape. The pressure in chamber *c* now immediately seeks to bring about a balance with that in chamber *b*, causing the piston *a* to be moved downwards and closing passage *a′* as soon as the pressure in chamber *b* falls enough below that remaining in chamber *c* to overcome the slight friction of the piston.

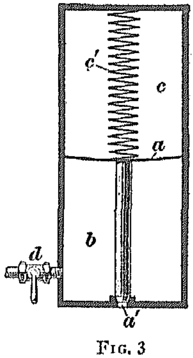


FIG. 3

13. Fig. 3 shows an arrangement of parts whereby the tendency for unbalanced pressures to balance can be employed to open and close a port when the pressures involved are due

to a combination of air and spring pressures. Fig. 3 shows chambers b and c separated by a thin diaphragm a which possesses a certain degree of flexibility in either direction. The diaphragm has a stem attached to it that normally closes port a'. The spring c' replaces air pressure, and if the pressure of the air entering chamber b through d is equal to the tension of the spring, no movement of the diaphragm or its stem will result. However, if the pressure in chamber b is increased above the downward pressure exerted by the spring, the diaphragm a will be deflected upwards, taking its stem with it and opening port a'. The air in chamber b will escape until it becomes less in pressure than that exerted by the spring c', after which the diaphragm will move downwards and seat its stem in port a'.

Although the movement of the parts in Figs. 1, 2, and 3 is due to the principle of unbalanced pressures endeavoring to reestablish a balance, yet this principle is usually stated in another way, the reason for the parts moving being ascribed to a greater pressure acting in opposition to a lesser pressure.

14. Application of Brake Principles.—The air brake consists of a closed system of reservoirs, cylinders, and moving parts and when operating it is charged with compressed air.

The parts upon which the operation of the brake depends derive their movement from diaphragms or pistons that are caused to operate by an inequality of pressures acting on them. Diaphragms are used to form a flexible partition between two sources of pressure, such as pressure due to compressed air on one side and the tension of springs on the other. However, in some cases, the pressure on one side of a diaphragm may be due to a combination of air and spring pressures.

A piston is used to form a movable partition between two pressures, these pressures being carried in two different receptacles, a pressure receiving its name from the receptacle in which it is stored.

Diaphragms are employed in devices designed to automatically maintain pressures at a predetermined amount, while pistons control the movement of parts directly employed to

secure the operation of the brake. The movement of diaphragms when operating is slight in comparison with the movement of the pistons.

15. Equality of pressures will cause no movement of the parts just mentioned, but an inequality brought about by increasing the pressure on one side of a piston or diaphragm causes it to move away from the now greater pressure toward the lesser pressure on the other side. Likewise a decrease in pressure on one side of a piston or diaphragm also destroys the previous equalization of pressures, the piston or diaphragm then being moved by the greater pressure on its opposite side toward the lesser pressure. The difference in pressure necessary for the operation of the brake is brought about by opening and closing the brake pipe to the atmosphere for an interval sufficient to result in the required difference of pressures being formed in the air-brake system to insure the movement of the operating parts. The difference in pressures in the auxiliary reservoir and brake pipe obtained by opening the brake pipe to the atmosphere causes the brake to apply, whether the opening is intentional or otherwise; closing off the brake pipe from the atmosphere and connecting this pipe to a source of higher pressure causes the brake to release. A balance or an approximate equalization of pressures in the auxiliary reservoir and brake pipe, which is obtained by maintaining the air in the brake pipe at a certain fixed pressure, or by preventing the inflow or outflow of pressure, causes the brake to remain released or applied.

16. The causes for the brake operating remain the same regardless of the number of times the parts or cars are duplicated. However, it is evident that it will become more difficult to produce the causes that result in an air-brake operation on a train of one hundred cars than on one consisting of one quarter of that number. As the volume of the brake pipe increases with its length, the length of time necessary to accomplish the change in pressure also increases. It then becomes more difficult to obtain the requisite difference in pressure necessary for the movement of the parts that govern brake operation,

and a slower application of the brakes will result, as the pressure cannot flow to the brake cylinders from the reservoirs on the cars faster than it can escape from the brake pipe. The release of the brakes will also be correspondingly slower on long than on short trains, as it takes a longer time to restore the brake-pipe pressure and therefore longer to obtain the necessary difference in pressure to move the parts that control the release of the brakes to release position.

WESTINGHOUSE AUTOMATIC AIR BRAKE

EXPLANATION OF DRAWINGS

17. In the descriptions of brakes, compressors, and other apparatus in this and following Sections, drawings are used to make plain the construction and methods of operation; and to assist the reader in understanding these drawings a brief description of the principles governing the making of them is here given. The terms used in referring to the different views of an object and the relations of the different views to one another are explained, as well as the methods employed for representing the different kinds of materials of which the object is composed.

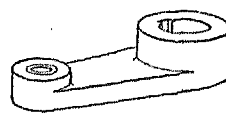


FIG. 4

18. Representation of Objects.—An object may be represented by a photograph, a perspective drawing, or by a mechanical drawing.

19. Perspective Drawings.—Perspective drawings are pictorial in character and appear as if made from photographs, which also are perspective views. A perspective view of an object is given in Fig. 4.

20. Mechanical Drawings.—A mechanical drawing does not represent an object as it would appear to the eye, but it shows its correct shape, and gives the true dimensions of the various parts. The number of views required depends

on the nature of the object, but two or three are usually sufficient to show the form.

The different views of the object are arranged according to a system, in which the front view is taken as the principal one, and the other views are grouped around, each being placed next to the side that it represents. A mechanical drawing, showing five views of the object illustrated in Fig. 4, arranged according to the American system, is given in Fig. 5. The front view is taken as the central view, the top view is placed above it, the bottom view below, and the side views each on the side from which the object is supposed to be seen.

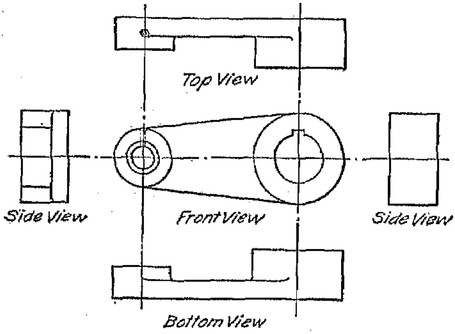


FIG. 5

If the object is not complicated, outside views are sufficient, but if the inside is of peculiar form, or if internal parts are to be shown, *sectional views*, or *sections*, are also given.

In Fig. 6 (*a*) is shown a full view of an object, with the interior part indicated by dotted lines, such lines being used to indicate surfaces, parts, or ports that are hidden.

In Fig. 6 (*b*) is shown how part *d* of the object shown in view (*a*) would appear if were cut through on the line *a b* and the part *c* were removed.

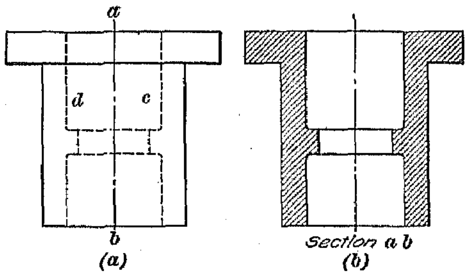


FIG. 6

21. Classes of Sections.—There are several kinds of sections, and these are named according to the manner or the

direction in which the object is assumed to be cut in making the section. A section taken by cutting across a body in the direction of its smallest dimension is called a *cross-section.*

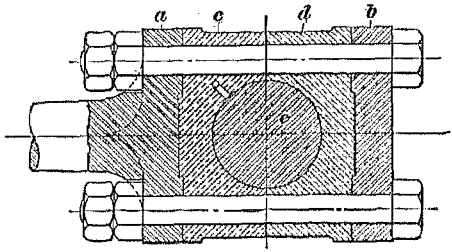


FIG. 7

If the section is taken in the direction of the greatest length of the body it is called a *longitudinal section.* If a cross-section or longitudinal section is made to show only part of the way through an object, it is then known as a *partial section* or a *half section.* Sometimes two or more sections of the object are given to show its construction at different points; but if two or more partial sections are combined in one view, they form what is called a *conventional section.*

22. Cross-Hatching.—One of the most noticeable features of the section, however, is the series of evenly spaced slanting lines drawn on it.

These lines are called *section lines* or *cross-hatching,* and indicate the surface along which the object is supposed to be cut in making the section.

In a sectional view when two or more pieces are fitted together, the section lines of adjacent pieces are slanted in different directions, so that the fact that the parts are not one piece may readily be seen. Thus, in Fig. 7 is shown a section of two steel pieces *a* and *b* bolted together, and

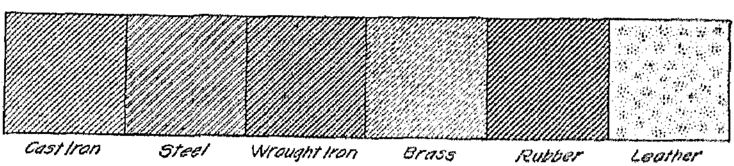


FIG. 8

between them two pieces of brass *c* and *d* which enclose a steel shaft *e.*

23. Forms of Cross-Hatching.—As many different materials are used in the construction of apparatus, it has become the custom to indicate these differences on the drawing by using a particular form of cross-hatching to denote each material. The practice is not the same in all manufacturing shops, as each adopts its own standards.

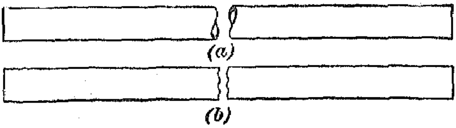


FIG. 9

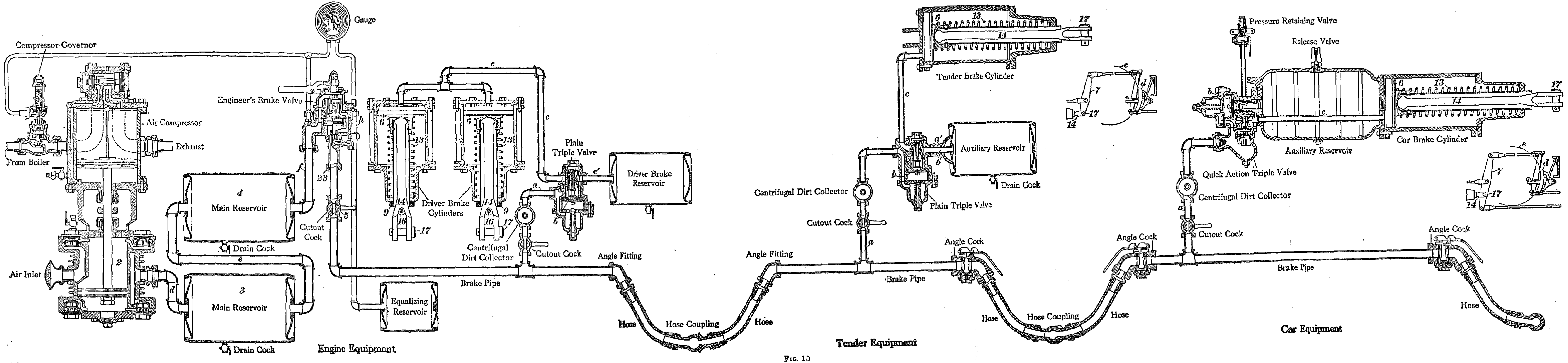
The list given in Fig. 8 represents the usual practice. Very often when the material from which the object is made is not important, plain section lines such as those indicating cast iron are used on the drawing.

24. Breaks.—A break is used when drawing a long slender object, such as a pipe, when space will not permit of its being drawn in full. In such a case, the view shows as if part of the object were broken out, and the remaining ends were drawn closer to each other as in Fig. 9 (*a*) or (*b*).

GENERAL ARRANGEMENT AND OPERATION OF THE AIR BRAKE

25. Names of Parts.—When studying the principles underlying the operation of the air brake, the least number of parts that make up an air-brake unit will be considered. Such parts comprise what is found on a locomotive and one car, as the locomotive has a storage reservoir and operating valve not found on a car.

Fig. 10 illustrates a single air-brake unit, as it shows the apparatus comprising a brake for an engine, tender, and freight car. The figure gives the names of the principal parts and also shows the arrangement of them. The important parts of the equipment on the engine are a steam-driven air compressor, a steam compressor governor, a main reservoir, an engineer's brake valve including an equalizing reservoir, and a feed valve (the latter not shown), a duplex air gauge, a brake pipe,



BB 514B 1957

Fig. 10

a triple valve, a driver brake reservoir, and two driver brake cylinders.

The apparatus comprising the automatic air brake on the tender and car consists of a triple valve, a brake pipe, an auxiliary reservoir, a brake cylinder, and, in addition, a pressure-retaining valve on the car.

The connection between the brake pipe on the engine, tender, and car is made by flexible hose and couplings.

While the brake arrangement shown on the locomotive is not of the latest type, being the A-1 equipment on the engine and the FL tender equipment, yet it is still in use, and moreover it lends itself more readily than more modern equipments to an understanding of the principles underlying the operation of the air brake; many of the parts shown are also duplicated in other equipments. The arrangement of the brake on the car is standard for freight service.

26. Charging the Brake System.—When the air compressor is operating, air is compressed and discharged from it through a pipe *d*, Fig. 10, to the first main reservoir *3*, after which it passes through pipe *e* into the second main reservoir *4*. From this latter reservoir the air flows through a pipe *f* to the engineer's brake valve, which is connected to the brake pipe by union nut *23*, and when the brake-valve handle is in the proper position, the air passes through the brake valve to the brake pipe. From the brake pipe, the air passes through the three branch pipes *a* to the triple valves on the engine, tender, and car and when these valves are in release position as shown, the air feeds by the triple pistons *b* through restricted passages not shown in this figure, and charges the auxiliary reservoirs. The auxiliary reservoir or driver-brake reservoir on the engine charges through pipe *c′* and on the tender through pipe *b′*, and on the car the auxiliary reservoir charges through the triple valve direct. The triple pistons with the exception of the restricted openings serve to separate the air in the brake pipe from that in the auxiliary reservoirs, and it is on these pistons that the air acts, and the difference in its pressure brings about the operation of the brake. When the

charging of the brake system is completed, the pressure in the auxiliaries and brake pipe is equal and the triple pistons *b* are balanced between equal pressures. The air in the brake cylinders at this time is at atmospheric pressure.

27. Applying the Brake.—The brake is applied by reducing the pressure in the brake pipe below the pressure in the auxiliary reservoir, which is done by moving the handle of the engineer's brake valve to the proper position, thus permitting the air in the brake pipe to escape. The balance of pressure heretofore existing on each side of the triple pistons *b*, Fig. 10, is destroyed, and the pistons are now moved by the higher pressure in the auxiliaries toward the lesser brake-pipe pressure. The movement of the triple pistons first closes the restricted passages between the brake pipe and the auxiliaries, after which the pistons operate certain valves that are attached to them in such a manner as to close the opening from the brake cylinders to the atmosphere, after which the valves open ports that permit air from the auxiliary reservoirs to pass to the brake cylinders on the engine, tender, and car through pipes *c*. The brake-cylinder pistons *6* and push rods *14* on the locomotive and car are forced outwards, and as the push rods are connected by pins *17* to a system of levers, part of which are shown on the tender and car and to which the brake beams are connected, the outward movement brings the brake shoes *d* up against the wheels *e*. The friction resulting from the pressure of the brake shoes against the wheel treads retards the movement of the train or bring it to rest, as may be desired. The system of levers, rods, brake beams, brake shoes and their attachments is known as the foundation brake gear. The levers *7*, to which the push rods *14* directly connect, are the cylinder levers.

28. Holding the Brake Applied.—The brake is held applied by moving the brake-valve handle to a position that stops the exhausting of brake-pipe air, the pressure in the brake pipe, except for leakage, now remaining stationary. The pressure in the auxiliary reservoirs, however, continues to reduce by passing to the brake cylinders, until the auxiliary

pressure falls slightly below the brake-pipe pressure, the result then being a slight movement of the triple pistons *b*, Fig. 10, away from the now greater brake-pipe pressure toward the lesser pressure in the auxiliaries. The valves already referred to as being operated by the triple pistons now operate in such a manner as not only to close the ports through which the auxiliary air passes to the brake cylinders, but also to stop the movement of the triple pistons, and prevent the slightly higher brake-pipe pressure from moving them all the way to release position. The brake is then held applied, due to an approximate equalization of the pressures in the brake pipe and the auxiliary reservoirs.

29. Releasing the Brake and Recharging the Auxiliaries.—The brake is released by increasing the pressure in the brake pipe above that in the auxiliary reservoirs. This difference in pressure is brought about by allowing the higher pressure stored in the main reservoir, Fig. 10, to pass to the brake pipe by moving the brake-valve handle to the same position as was used when charging the brake system. The difference in pressures now existing on either side of the triple pistons carries them and their attached valves to the limit of their travel toward the lesser auxiliary pressure; these valves now allow the pressure in the brake cylinders to exhaust through pipes *c* and suitably arranged ports in the triple valves to the atmosphere, and the brake releases, the brake-cylinder pistons being moved to normal position by the release springs *13* in the brake cylinders. The auxiliary reservoirs again charge equal to the pressure in the brake pipe through the restricted openings already named.

A detailed description of the operation of a triple valve will be given in another Section.

PURPOSE OF THE PARTS

30. Steam-Driven Air Compressor.—The purpose of the steam-driven air compressor is to compress the air for use in the brake and signal apparatus, as well as for the operation of certain auxiliary devices.

31. Steam Compressor Governor.—The duty of the steam compressor governor is automatically to stop and start the compressor by regulating the steam supply to it, when the pressure in the main reservoir reaches or falls below a predetermined pressure.

32. Main Reservoir.—The main reservoir serves to receive and store the air compressed by the compressor, and it also acts as a cooling chamber for the air and catches the moisture precipitated from it.

33. Engineer's Brake Valve.—The purpose of the engineer's brake valve with slide valve feed-valve is, (*a*) to admit air from the main reservoir to the brake pipe when the brakes are being released; (*b*) to maintain a predetermined pressure in the brake pipe when the brakes are not being operated; (*c*) to allow the air to escape from the brake pipe when the brakes are being applied; and (*d*) to prevent the passage of air to or from the brake pipe when the brakes are being held applied.

34. Brake Pipe.—The purpose of the brake pipe, which includes the branch pipes to the triple valves, air hose, and couplings, is to connect the brake valve and conductor's valve in passenger cars and cabooses with the triple valve on each car. Angle cocks are placed in the brake pipe on each car so that the pipe may be opened or closed at any particular point in the train, and the cut-out cocks in branch pipes are provided to cut a triple valve in or out of service as desired. The handles of the angle cocks stand lengthwise of the brake pipe when open, while the handles of the cut-out cocks stand crosswise of the pipe when open.

35. Triple Valve.—The purpose of the triple valve is to charge the auxiliary reservoir by connecting it with the brake pipe, to apply the brake by connecting the auxiliary reservoir with the brake cylinder, to release the brake by connecting the brake cylinder with the atmosphere, and to hold the brake applied by closing all communication between the brake pipe, auxiliary reservoir, brake cylinder, and atmosphere.

36. Auxiliary Reservoir.—The purpose of the auxiliary reservoir is to store compressed air for applying the brake on the car or locomotive on which it is placed.

37. Brake Cylinder.—The brake cylinder is used to convert the power in the compressed air to force, which is transmitted by a leather-packed piston operating within the cylinder, to the cylinder lever of the foundation brake gear and to the brake shoes when the brakes are applied.

38. Duplex Air Gauge.—The purpose of the air gauge is to indicate the pressure carried in the main reservoir and the brake pipe.

39. Pressure-Retaining Valve.—The purpose of the pressure-retaining valve is to permit the free discharge of air from the brake cylinder to the atmosphere during a release of the brake when the handle is turned down. With the handle turned up, the valve restricts the discharge of air from the brake cylinder to the atmosphere and finally retains a predetermined amount therein, with the triple valve in release position. Pressure-retaining valves are used on grades to keep the brakes applied while the auxiliaries are being recharged.

DESCRIPTION OF MAIN RESERVOIR

40. The main reservoir, Fig. 10, is an air-tight cylinder having a pipe connection with the air compressor, and one with the engineer's brake valve. Two main reservoirs are now generally used with a radiating pipe between them as shown in Fig. 10, such an arrangement being more efficient in cooling the air and precipitating the moisture than when a

single reservoir is used. The engineer's brake valve is piped to the main reservoir farthest from the compressor, as the air in this reservoir is cooler. The main reservoir varies in size according to the kind of service in which the engine is employed, and the reservoir's total capacity should be not less than 40,000 cubic inches for passenger and switching service, and 60,000 cubic inches for freight service. When the main reservoir is of large capacity, a large volume of compressed air is available for releasing the brakes and recharging the auxiliaries, thus avoiding excessive speed of the compressor at such times with consequent overheating and excessive wear. A higher pressure is required in the main reservoir than in the brake pipe, not only to release the brakes, but also to force the air through the brake pipe in the shortest time possible and thus release all brakes on a long train promptly. The pressure carried in the main reservoir, which is higher than that in the brake pipe and varies under operating conditions, is called excess pressure; and with the air-brake system charged and the brakes not operating, the difference is about 20 pounds but varies with equipment and conditions of service. The usual main-reservoir pressure carried is 90 pounds.

41. Water in Main Reservoirs.—Air always contains some moisture in the form of an invisible vapor. The amount of this moisture depends upon the atmospheric temperature, and the opportunity of the water to reach the air; the higher the temperature of the air, the greater amount of water vapor it can contain. Thus, at 60° F., 5.75 grains of moisture can be contained in a cubic foot of air, while at 120° F. the 1 cubic foot may contain 34.11 grains. Lowering the temperature of the air will cause some of the water vapor to condense to water, which is the case when the reservoirs become cooled.

Compressed air contains more water vapor than does a like volume of free air. Thus, to obtain a main-reservoir pressure of 90 pounds requires that 7 cubic feet of air at atmospheric pressure be compressed into 1 cubic foot. Therefore, 1 cubic foot of air at 90 pounds pressure contains all the moisture that was in 7 cubic feet before compression. In

case the 7 cubic feet of air before compression contained all the moisture that could be held at the atmospheric temperature, then after the 7 cubic feet have been compressed into 1 cubic foot, and the temperature has become the same as before, $\frac{6}{7}$ of the moisture, or the moisture out of 6 of the 7 cubic feet, would condense.

42. With the compressor working rapidly against a pressure of 90 pounds, the air delivered into the main reservoir has a temperature of about 300° F. As the amount of moisture that the air will contain increases rapidly with its temperature, the heating during compression prevents any moisture from being deposited in the compressor. But as the air cools in the reservoir down to its original temperature, it will gradually drop its surplus moisture. If this cooling can be accomplished before the air leaves the last main reservoir, very little moisture will be carried into the brake pipe. The higher the temperature of the compressed air above the atmosphere when it leaves the last main reservoir, the more moisture will be carried into the brake system. In order to keep the brake pipe dry, it is essential therefore that the air be cooled as much as possible before it leaves the last main reservoir.

43. The means employed to cool the air is to use two main reservoirs, placed in a relatively cool location, with a considerable length of piping between the compressor and the first main reservoir, and also between the two reservoirs. As the main reservoirs have too little surface for the large body of air to be cooled, they accomplish little of the needed cooling. Pipes run in the coolest possible location afford the best means of cooling the air. The discharge pipe from the compressor should be from 35 to 45 feet long, and the reservoir connecting pipe should be from 40 to 60 feet. With main reservoir under the running boards forward of the firebox, these cooling pipes should run back and forth on the outside of the reservoirs, and should slope to drain with the flow of air.

44. The main reservoirs should be drained before each trip by means of the drain cocks provided for this purpose in

the bottom of the reservoirs. When water is allowed to accumulate in the main reservoirs, it reduces the space available for storing air, and thereby interferes with the proper release of the brakes, and lengthens the time of recharging the auxiliaries on long trains. Water is also liable to be carried into the brake system and thus prevent the brakes from operating properly.

DESCRIPTION OF DUPLEX AIR GAUGE

45. A duplex air gauge, which indicates both brake-pipe and main-reservoir pressures, is located in the engine cab in a position convenient for the engineer. This gauge, shown in Fig. 11 (*a*) and (*b*), consists of two gauges combined in one, the same dial serving for both hands. The one gauge, which as seen connects with *M*, operates the black hand. This hand is said to represent brake-pipe pressure, although *M* really has a pipe connection to the equalizing reservoir *h*, Fig. 10; but the study of the engineer's valve will develop the fact that there is direct connection between the equalizing reservoir and the brake pipe in release and running positions, but not in service, lap, or emergency positions. The other gauge connection *T*, Fig. 11, is piped to the main-reservoir air in the brake valve, so that this hand, which in the actual gauge is colored red but in the illustration is light colored, indicates main-reservoir pressure.

46. Principle of Working.—An inside view of the air gauge is shown in Fig. 11 (*b*), in which *A* and *B* are two bent tubes of elliptical shape, as shown in (*d*). The tube *A* is connected to the fitting *M*, and the tube *B* to the fitting *T*. The bottom ends of the tubes are held fast and the top ends are closed and free. The action of the gauge may be thus explained: If a tube of elliptical section is bent as shown in view (*d*), and then subjected to an internal pressure (of either a gas or a liquid) the force exerted will tend to straighten the tube. This is due to the fact that the force exerted within the tube tends to make it assume the circular form shown dotted in view (*c*). In assuming the circular form, the con-

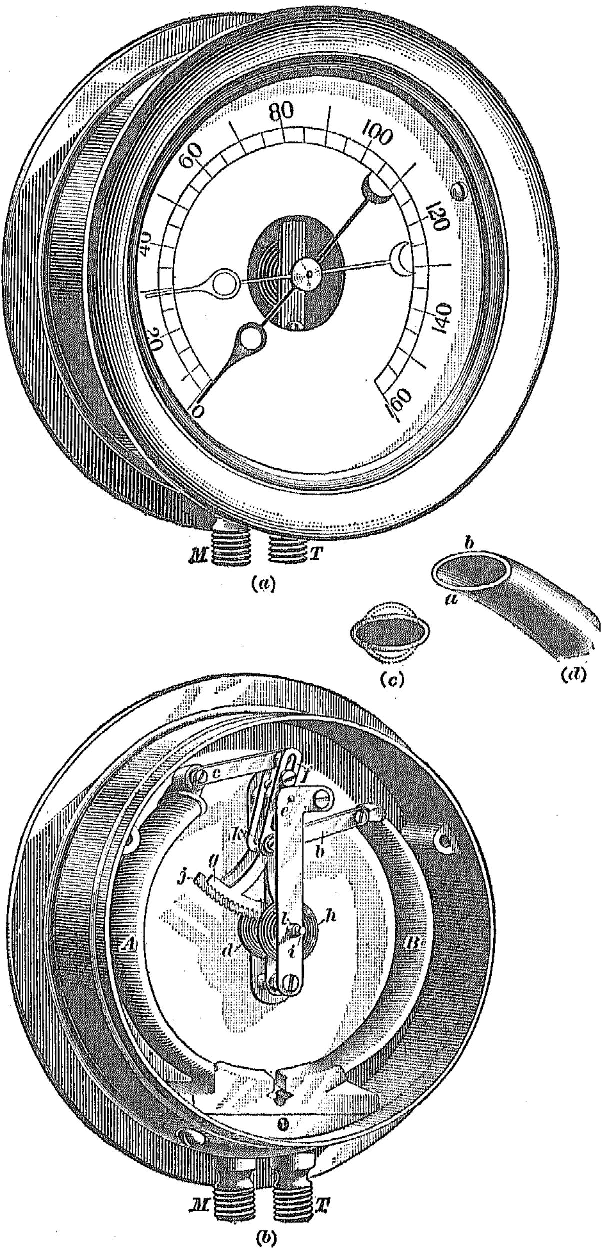


FIG. 11

cave side a, view (d), of the bent tube tends to lengthen, while the convex side b tends to shorten. These combined efforts tend to straighten the tube out, and therefore impart a movement to its free end.

Tube A is connected to one end of the lever kj by means of the link c. This lever is pivoted at e, and the end j forms a toothed sector which meshes with a pinion on the spindle i that carries the black hand and that turns within the spindle l. Tube B is connected by link b to the lever fg at a point below the fulcrum, or pivot; the lower end of the lever forms a toothed sector that meshes with a pinion on the hollow spindle l and operates the red hand.

47. Operation of Gauge.—Since brake-pipe pressure connects with M, Fig. 11, air under pressure enters tube A and tends to straighten it out. This causes the free end of A to move to the left, drawing the link c with it, thus moving the toothed sector j to the right. As this sector engages with the spindle i, the latter is made to move clockwise, that is, to have a motion in the same direction as the hands of a clock. The black hand is thus given a similar motion.

Main-reservoir pressure acts within the tube B to straighten it out, and the free end is moved to the right. As the bar b is connected below the fulcrum of the lever fg, the movement of the free end of B will cause the toothed sector g to move to the right on the pinion on the hollow spindle l and turn the red hand clockwise also. The greater the pressure within the tubes, the greater will be the tendency for them to straighten out, and the higher will be the pressure registered by the gauge; d and h are small coil springs to take up the play or backlash in the teeth of the sector and pinion.

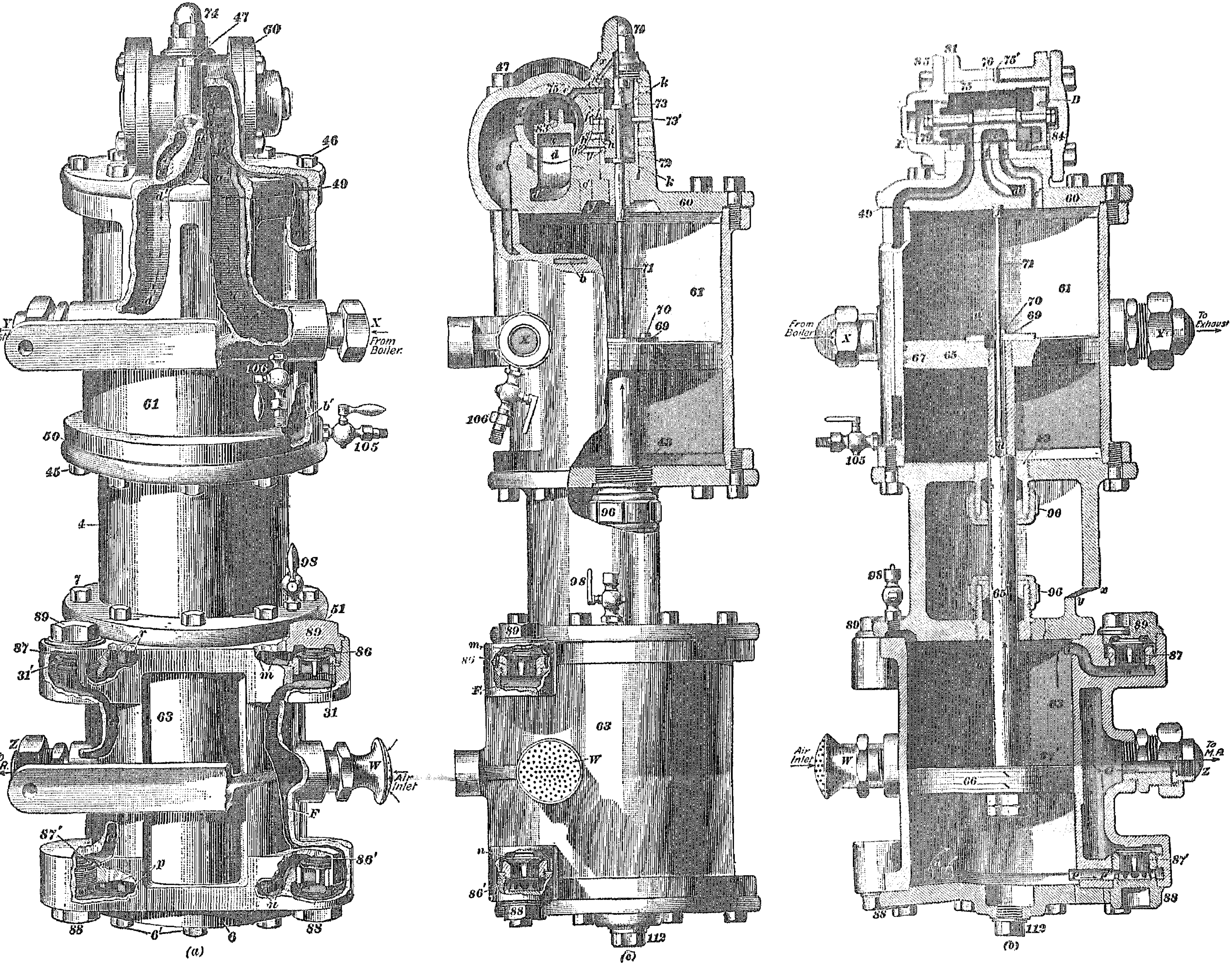


Fig. 12

COMPRESSORS

THE $9\frac{1}{2}'' \times 9\frac{1}{2}'' \times 10''$ AIR COMPRESSOR

48. Views of the Compressor.—The first two numbers in the name of the air compressor refer to the diameter of the steam and air cylinders, and the last one to the length of the piston stroke. The compressor here described is commonly known as the "$9\frac{1}{2}$-inch compressor."

Fig. 12 shows three views of the $9\frac{1}{2}$-inch compressor, and Figs. 13 to 20, inclusive, show details of various parts. In Fig. 12 (*a*) is a back view in which portions of the steam and air passages are broken away, in (*b*) is a cross-sectional view, and in (*c*) is a side view showing a section through the top head *60*, a portion of the steam cylinder also being shown broken away.

49. General Description.—The $9\frac{1}{2}$-inch compressor, Fig. 12 (*a*), consists of two principal parts, an upper part *60* and *61*, which is a steam engine, and a lower, or air, part *63* in which the air is drawn in, compressed, and discharged into the main reservoir. Air is compressed by the up-and-down movement of an air piston *66* in the air cylinder *63*, view (*b*); this piston receives its movement from a steam-driven piston *65* in the steam cylinder *61*, and the movement of piston *65* is transmitted to the air piston *66* by a piston rod *65′* to which both pistons are connected, the steam piston being screwed on to the piston rod and the air piston being secured to the rod by nuts. The steam portion of the compressor, view (*b*), consists of two parts, a steam cylinder *61*, containing the steam piston *65* and a top head *60*, which contains an arrangement of valves which when operating so distribute the steam to and from the steam cylinder as to cause a continuous movement of the steam piston *65* and therefore of the air piston *66*. The top head *60*, the lower face of which forms a cylinder head for the upper end of the steam cylinder *61*, is attached to the cylinder by means of capscrews *46* and a capscrew *47*, view (*a*), a copper gasket *49* being placed between the top head and the steam

cylinder to insure a steam-tight joint. The steam and air cylinders are connected to a common center piece *4*, the center piece forming the lower steam-cylinder head and the upper air-cylinder head. The lower air-cylinder head *6* is attached to the air cylinder by capscrews *6'*.

50. The movement of the valves in the top head necessary to distribute the steam so as to keep the steam piston *65* operating is accomplished by a reversing plate *69*, view (*b*), on the steam piston *65*; this plate *69* comes in contact with a shoulder *j* on the upper part of the reversing rod *71* and a button *u* on the lower end of the rod as the steam piston nears the top and bottom of the stroke, the rod at other times being stationary, since a portion of the piston rod *65'* is hollow and can therefore move up and down without moving the reversing rod except as stated. Therefore, the valves controlling the movement of the steam piston *65*, unlike the ordinary steam engine, do not have a continuous movement, but only operate at about the completion of the piston stroke, their movement at this time being such as to cause the steam piston to move in the opposite direction.

51. The air cylinder *63* in addition to air piston *66* contains an arrangement of air valves *86*, *87*, *86'* and *87'*, view (*a*), which are opened and closed due to a difference of air pressure caused by the movement of the air piston. These valves in connection with the proper arrangement of air passages, permit air to be drawn through the air inlet *W*, compressed in the air cylinder, and discharged to the main reservoir at *Z*.

52. Description of Steam Cylinder and Top Head. The general arrangement of the steam passages in the steam cylinder and top head is shown in Fig. 12 (*a*) and is similar to the ordinary steam engine, which requires a passage for the admission of steam from the boiler to a steam chest, an arrangement of steam passages to each end of the steam cylinder, and an exhaust port. In view (*a*) the steam from the boiler enters the compressor at *X* and passing through a passage *a* in the wall of the steam cylinder enters certain chambers in the top

head *60*, these chambers serving as steam chests for certain valves which are not shown in this view. Passage *b′* leads through the wall of the steam cylinder to the lower end of the cylinder, passage *c′* leads to the upper end of the cylinder, and *d′* in the wall of the steam cylinder is the exhaust passage through which the steam escapes at *Y* after it has performed its work of moving the steam piston.

The passages *a*, *b′ c′*, and *d′* in the steam cylinder terminate in ports *a′*, *b*, *d*, and *c* in the main valve bush *75* in the top head, view (*b*), and lead into chamber *A*. The color scheme shows that live steam is passing to the lower end of the cylinder, and exhaust steam is escaping from the upper end to the exhaust passage *d′*.

Drain cock *105*, view (*a*), which is located in passage *b′*, and *106*, which is located in passage *a*, are provided to permit the escape of condensation from the steam cylinder and the steam passage when starting the compressor. The steam piston *65* is caused to work steam-tight in the cylinder by two packing rings *67*, view (*b*).

53. The top head contains the two valves on which the operation of the steam piston, and therefore of the air piston depends. On account of their location, only one can be shown in the same view. In Fig. 12 (*b*) is a sectional view of the top head which shows the valves that directly effect the movement of the steam piston *65*, as well as the arrangement of the steam ports. This section of the top head contains the main valve piston *76*, so called as it imparts movement to the main slide valve *83*. The main valve piston consists of two pistons *77* and *79* of unequal diameter mounted on a stem *81*, to which the pistons are attached by the nuts shown. As the pistons *77* and *79* are of different areas, they are sometimes referred to as the differential pistons. The main slide valve *83* is held between the two collars shown on the stem *81*, so that any movement of the main-valve piston *76* will also be communicated to the main slide valve *83*. Piston *77* and slide valve *83* operate within the main-valve bush *75*, this bush forming a steam chest for the valve, while piston *79* operates within

the cylinder head *85*. The main slide valve *83*, which is of the D type, is moved at stated intervals by the main valve piston *76* across the three ports *b, d,* and *c* in the bush, and by so doing controls the admission of steam to and the exhaust of steam from the steam cylinder in such a way as to keep the steam piston *65* operating. The valve *83* whose seat is formed by a flat portion of bush *75* admits steam from chamber *A* to the steam cylinder past its outer ends and exhausts it through a cavity *v* in its interior, and it will be noted in view (*b*) that when the valve opens one port for the admission of steam to one end of the cylinder, it at the same time connects the other two ports, which then results in the other steam port being connected to the exhaust port.

54. Reversing-Valve Arrangement.—The reversing-valve arrangement necessary to cause the main-valve piston and slide valve to move at the proper time in relation to the movement of the steam piston, is shown in Fig. 12 (*c*). Because the part containing the reversing-valve arrangement had to be omitted when the section of the top head shown in view (*b*) was drawn, it became necessary to show the arrangement in another section as in (*c*). The movement of the main-valve piston and the slide valve in the proper direction at the proper time is accomplished by the vertically operating reversing rod *71*, view (*c*), which actuates the reversing valve *72* in such a manner in connection with the proper arrangement of ports as to admit steam to and exhaust steam from chamber *B*, view (*b*), just as the steam piston nearly completes its stroke, the movement of the reversing valve being due to the reversing plate *69* on the steam piston striking the extremities of the reversing rod *71* in the steam cylinder at such times. Therefore, the steam piston receives its movement from the action of the main-valve piston *76* and slide valve *83*, and these parts in turn are caused to move by the action of the reversing valve *72*. Fig. 13 shows the arrangement of the ports in the top head which enables the reversing valve to admit steam to and exhaust steam from chamber *B* and insure the movement of the main-valve piston *76* and slide valve *83*.

55. In Fig. 13, part of the reversing-valve-chamber bush *73* is shown cut away, as well as a part of the top head *60* that surrounds the main-valve bush *75*. The reversing valve *72* is also shown in the bush *73*. The bush *73* is kept supplied with live steam from chamber *A* through port *e*, and *e'*, Fig. 12, view (*c*), and the bush thus forms a steam chest for the reversing valve *72*. The part of the interior of the bush into which ports *g*, *h*, and *f* are drilled forms a seat for the reversing valve. Port *g* connects to the horizontal grooves *g'*

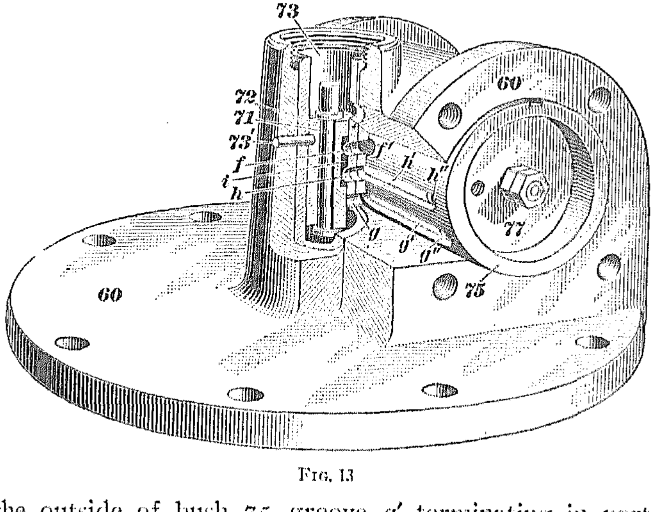


FIG. 13

in the outside of bush *75*, groove *g'* terminating in port *g''*, which extends through the bush into the space in front of piston *77*, or chamber *B*.

Port *h* connects to the horizontal groove *h'* in bush *75*, this groove terminating in port *h''*, which extends into chamber *B*.

Port *f* connects to groove *f'*. Groove *f'* does not enter the interior of the main-valve bush *75*, but is a groove in the shape of an inverted L, as in Fig. 14, running to the left and then down around the bush into the main exhaust port *d*, Fig. 12.

It will be explained when considering the operation of the compressor why the action of the reversing valve in admitting steam to and exhausting steam from chamber *B* just as the steam piston completes either stroke, causes the main-valve

piston *76* to move the main slide valve *83* in such a way as to keep the steam piston *65* moving.

Pin *73'* is driven through the top head and bush *73* and extends into the interior of the latter, this portion of the pin engaging with slot *l* in the reversing valve, Fig. 16, thereby keeping the valve in its proper position, and also keeping the bush from turning.

56. The steam pressure in the reversing-valve chamber forcing the reversing valve against its seat creates sufficient friction to prevent the valve moving except when actuated by the reversing rod. The upper end of the reversing rod, Fig. 12 (*c*), works freely inside the reversing-valve-chamber cap *74*. A balance port *x* extends from a chamber in the cap *74* above the reversing rod through the top head to the upper end of the steam cylinder. This port is provided to assure the same pressure above as below the reversing rod whether there is live or exhaust steam in the upper end of the steam cylinder. The reversing rod and valve can be removed from the compressor by taking off the cap nut *74*, Fig. 12, view (*c*), and forcing the pistons upward about half way in their cylinders by removing plug *112* in the lower cylinder head. The reversing rod can then be pulled upward sufficiently to permit of the rod being worked sidewise and the button *u* can now be pulled through the offset hole *u'* in the reversing plate, shown in Fig. 12, view (*b*).

57. Description of Air Cylinder.—A back view of the air cylinder showing the air valves and the air passages broken away is shown in Fig. 12 (*a*). Air is drawn into the air cylinder at the air inlet *W* and discharged to the main reservoir at *Z*. The air cylinder contains two inlet valves *86* and *86'* and two discharge valves *87* and *87'*. All these valves move upwards to open and downwards to close, their lift being $\frac{3}{32}$ inch.

58. The purpose of the inlet valves is to permit of the air being drawn into the air cylinder during the suction stroke of the air piston and to prevent its escape from the cylinder during the compression stroke.

59. The purpose of the discharge valves is to permit of the air being discharged from the air cylinder to the main reservoir during the compression stroke of the air piston and to prevent the return of the air to the cylinder during the suction stroke. Passage *F* leads from the air inlet to the lower faces of the receiving valves *86* and *86'*, and passages *m* and *n* connect the tops of these valves to the interior of the air cylinder. The passages *r* and *p*, view (*b*), lead from the air cylinder to the under side of the discharge valves *87* and *87'*. Passage *G* leads from the top of the discharge valves to the main-reservoir connection *Z*.

60. The upper inlet valve *86* and upper discharge valve *87*, view (*a*), operate between valve seats *31* and *31'* and the valve caps *89*. The valve seats are screwed into projections on the air cylinder. The lower inlet valve *86'* and lower discharge valve *87'* operate on the upper end of valve cages *88*, which are screwed into projections on the side of the air cylinder. Connection between the lower end of the air cylinder and the lower face of the discharge valve *87'* is made through the circular holes shown in the valve cage. Similar openings in the inlet valve cage connect the lower face of inlet valve *86'* with passage *F*. The air valves in this type of compressor are interchangeable.

61. The air piston *66* has two packing rings. The piston rod *65'* is packed by a stuffingbox *40*, view (*b*), which is screwed into the centerpiece. The packing is held by the gland shown between the stuffingbox and the gland nut *96*. A similar arrangement is used where the piston rod passes through the center piece forming the lower steam cylinder head. The air-cylinder oil cup is marked *98*.

DETAILS OF COMPRESSOR

62. Main-Valve Bush.—Fig. 14 shows the main-valve bush *75*. This bush forms a steam chest for the main-valve piston *77*, Fig. 12 (*b*), and slide valve *83*, which operate within it. The steam from main steam passage *a*, Fig. 12 (*a*), enters

the bush through port a', and the reversing-valve bush is supplied with steam from this bush through port e. The slide-valve seat containing ports b, d, and c extend through the bush and connect with corresponding ports in the top head, as shown in Fig. 12 (b). The arrangement of the ports and grooves shown on the exterior of the bush has already been explained. Port t is connected by an interior passage to groove f'.

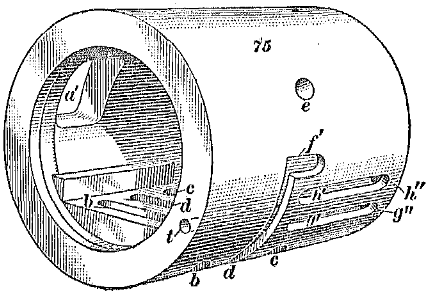


FIG. 14

63. Reversing-Valve-Chamber Bush.—The reversing-valve-chamber bush is shown in Fig. 15. This bush forms a steam chest for the reversing valve which operates within its interior. The reversing rod passes through a hole in the lower end of the bush. The ports e', f, h, and g extend through the bush into its interior.

64. Reversing Rod, Reversing Valve, and Reversing Plate.—The reversing rod, reversing valve, and reversing plate are shown in Fig. 16 (a), (b), and (c).

A slot l in the back of the reversing valve permits it being placed on the rod between the two shoulders a. A groove on the top of the slot prevents the valve from being placed on the rod upside down. The reversing plate is secured to the top of the steam piston by two bolts which pass through the holes b, view (c). The portion of the reversing rod between points j and u passes freely through the small hole d in the reversing plate when the steam piston is moving. The purpose of the large hole d' which connects with d is to permit the reversing rod to be removed and replaced as this hole is sufficiently large to permit the button u on the reversing rod to pass through it.

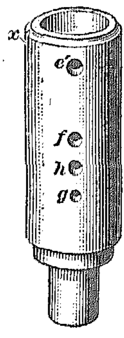
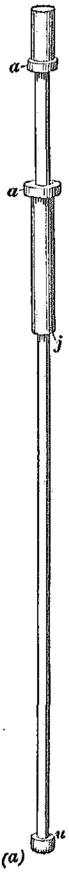


FIG. 15

65. Upper Inlet Valve, Valve Seat, and Valve Cap. In Fig. 17 (*a*) is shown the upper air inlet valve *86*, valve seat *31* with one side broken away, and valve cap *89* assembled as when placed in the compressor. In view (*b*) is shown the lower face of the valve cap *89*. Passage *F* from the air inlet leads up into the interior of the valve seat, and the space above the receiving valve *86* is connected by passage *m* to the upper end of the air cylinder. The valve seat *31* is screwed into a projection on the air cylinder, its upper end forming a seat for the inlet valve *86*. When the valve cap is screwed down, lugs *a* on the valve cap *89* come in contact with the upper part of the valve seat *31* and thus prevent the latter from working up. The lift of the upper inlet valve is restricted to the distance between the raised portion of the top of the valve and the boss *b* on the valve cap *89* directly above it. The upper inlet-valve cap and valve seat are similar to the discharge-valve arrangement on the same end of the air cylinder and are interchangeable.

66. Discharge-Valve Cage.—The lower



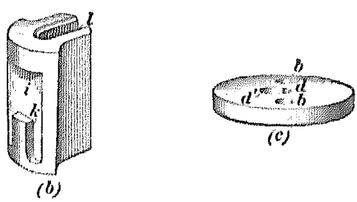


Fig. 16

discharge-valve cage *88* and the discharge valve *87′* seated on its upper part are shown in Fig. 18, a portion of the cage being shown broken away. The valve cage is screwed into a projection on the air cylinder. The circular openings *p′* connect to a

passage that leads to the lower end of the air cylinder, and the space above the discharge valve *87′* is in communication with the main reservoir. Air therefore is forced through openings *p′* into the interior of the cage *88* and, unseating valve *87*, passes to the main reservoir. The lower discharge-valve cage is interchangeable with the lower inlet-valve cage.

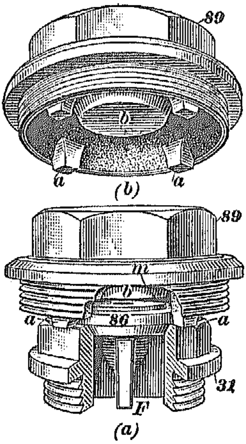


FIG. 17

67. Left Main-Valve Cylinder Head.—Fig. 19 shows a view of the left main-valve cylinder head *85* with one side broken away. The small piston *79* of the main-valve piston, Fig. 20 (*a*), operates within this head, the space between the head and the left side of the piston *79* being known as chamber *E*. Port *t′* and passage *t* connect with passage *t* in the main-valve bush *75*, Fig. 14. Port *t′* and passage *t* prevent any leakage from chamber *A* past the packing rings on piston *79* from accumulating in chamber *E*.

68. Main-Valve Piston and Main Slide Valve.—In Fig. 20 (*a*) is shown the main-valve piston, and in view (*b*), the main slide valve. The top of the main slide valve *83* is slotted, and sets between collars *a* when assembled on the stem *81*. The main valve piston consists of pistons *77* and *79* mounted on a stem *81*, the pistons being placed on the stem between the collars *a*, and the nuts on either end of the stem. The purpose of the main-valve piston is to transmit movement to the main slide valve *83*.

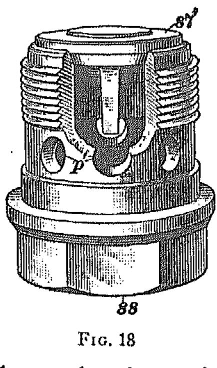


FIG. 18

69. The purpose of slide valve *83* is to admit steam to one end of the steam cylinder and exhaust it from the other end just as the steam piston completes either

stroke. Steam is admitted past either end of the valve, and exhausted through cavity *v*.

70. Diagrammatic Views of Compressor.—The views of the compressor in Fig. 12 show its actual construction. In order to show the interior of the main-valve bush *75* and main-valve piston *76*, as in view (*b*), it is necessary to assume the top head *60* of the compressor to be cut through horizontally and the front portion removed, and as this latter portion contains the reversing valve *72* and bush *73*, these parts cannot be shown in this view. Also it is necessary in order to show the interior of the reversing-valve bush to assume that the top head is cut vertically through the center as in view (*c*), in which event the portion removed contains piston *77*, which therefore cannot be shown. Therefore, to show the main-valve piston *76*, it is necessary to cut the reversing-valve bush *73* away, and in order to show this bush it is necessary to cut away a part of the main-valve piston *76*, the construction of the compressor being such as to prevent showing all parts in one view. For this reason two diagrammatic views of the compressor are given in Figs. 21 and 22, which means that the ports, passages, and operating parts are arranged other than they are in the actual apparatus, or all in the same plane. Figs. 21 and 22 will be used when explaining the operation of the steam and air ends of the compressor as they are much easier to understand than the real views shown in Fig. 12.

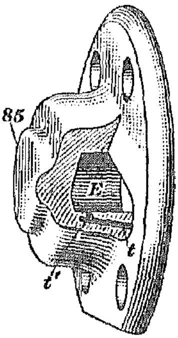


Fig. 19

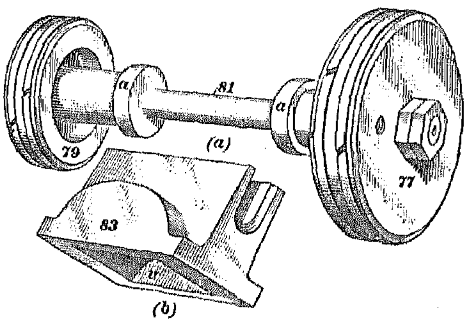
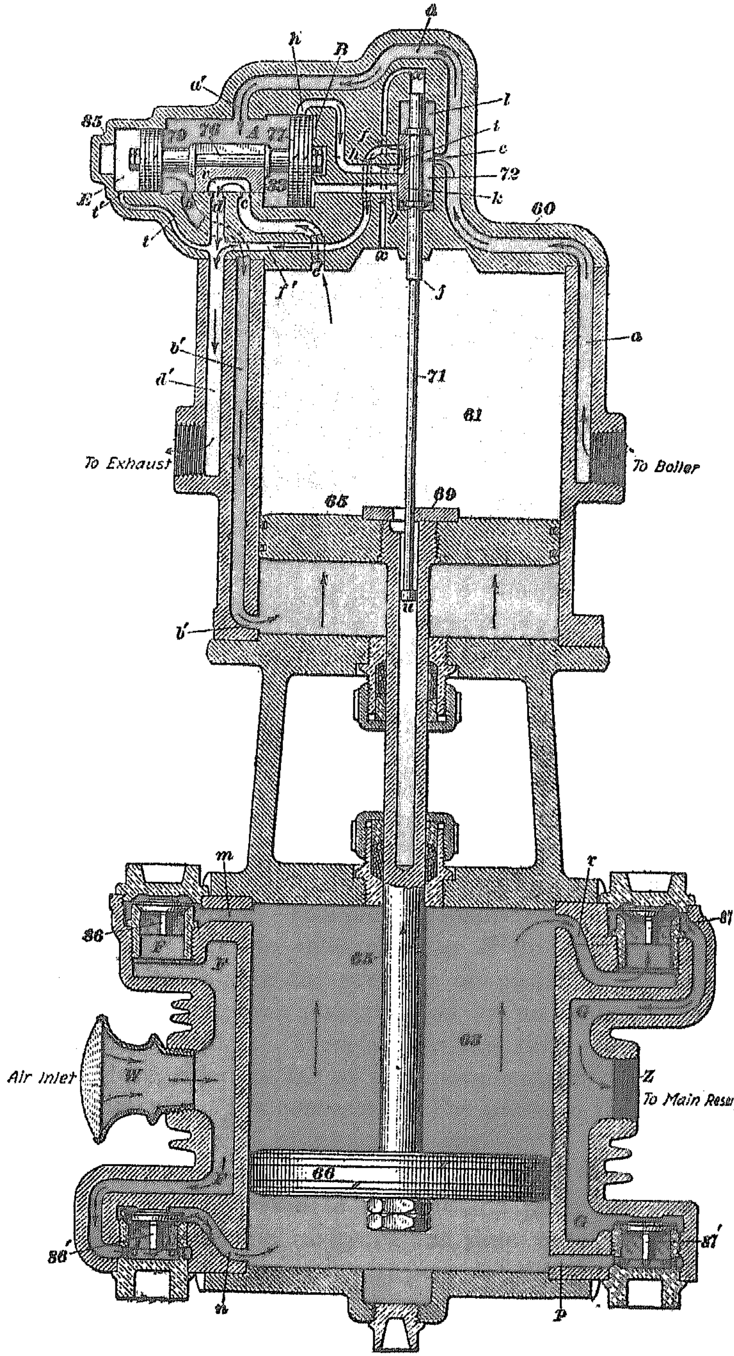


Fig. 20

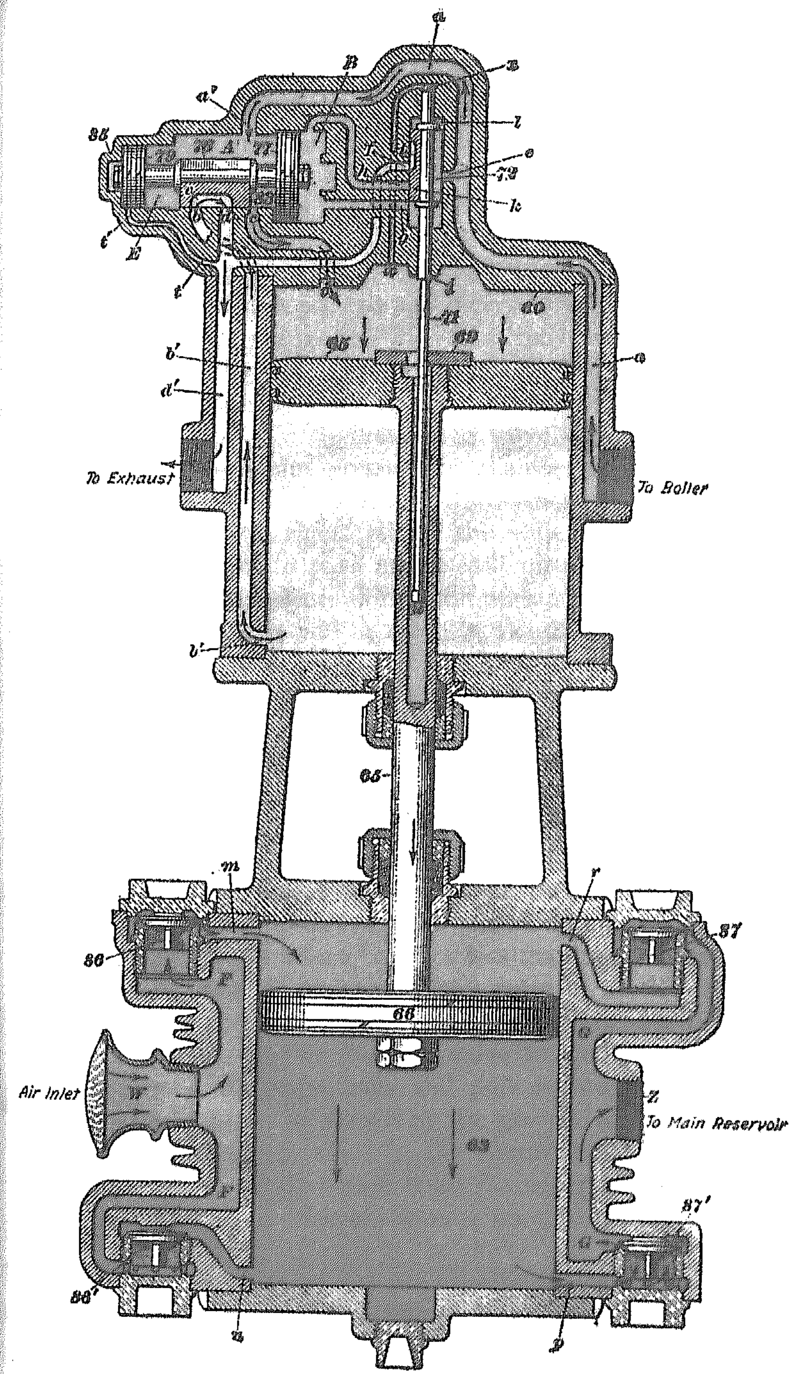
Fig. 21 shows the steam and air pistons *65* and *66* on the up stroke and Fig. 22 shows these pistons on the down stroke.

71. Operation of Steam Cylinder.—When the compressor is at rest, the pistons *65* and *66* generally settle to the bottom of their cylinders, and the under side of the reversing plate *69*, Fig. 21, strikes against the button *u* on the reversing rod *71* and pulls the reversing valve *72* down into the position shown, which connects chamber *B* at the outer end of piston *77* to the steam exhaust port *d* and passage *d′* through port *h*, cavity *i* in the reversing valve, port *f*, and passage *f′*. Steam enters the compressor at the boiler connection shown and, passing through passage *a*, enters chamber *A* in the main-valve bush through port *a′*, and owing to the area of piston *77* being greater than that of piston *79* and to the absence of pressure in chambers *B* and *E*, the main-valve piston *76* and slide valve *83* are forced to the right as shown in Fig. 21. Steam then passes down through port *b* and passage *b′*, and enters the cylinder below piston *65*, forcing the latter upwards. Any steam that may be above piston *65* exhausts through the passage *c′*, port *c*, the cavity *v* in the slide valve *83*, port *d*, passage *d′*, and out of the exhaust. As the steam piston nears the end of its upward stroke, the top side of the reversing plate *69* strikes the shoulder *j* on the reversing rod *71* and forces the reversing valve *72* upwards until part *k* opens port *g*, Fig. 22, and blanks port *h*. This permits steam from the reversing-valve-chamber bush to enter chamber *B* through port *g*, and practically to balance the pressure on piston *77* of the main-valve piston *76*, thus giving piston *77* no tendency to move in either direction. Therefore, at this time the piston *77* may be disregarded as far as any movement imparted by it to the slide valve *83* is concerned. The pressure then acting on the inner face of piston *79*, as chamber *E* is always open to the exhaust passage *d*, through port *t′* and passage *t*, forces the main-valve piston to the left and pulls the slide valve *83* with it until the cavity of the slide valve *83* connects port *b* in its seat with exhaust port *d*. When the slide valve is in this position, the steam port *c* is uncovered and



To Exhaust
To Boiler
Air Inlet
To Main Reserv

FIG. 21



To Exhaust
To Boiler
Air Inlet
To Main Reservoir

FIG. 22

steam from chamber *A* flows down through the passage *c′* into the steam cylinder above the steam piston, forcing it downwards. The steam below the piston then passes through passage *b′*, port *b*, cavity *v*, port *d*, and passage *d′* to the exhaust. As the piston nears the end of its downward stroke, the bottom side of the reversing plate *69* strikes the button *u* on the reversing rod *71* and pulls the rod and reversing valve downwards to the position shown in Fig. 21. This movement of the valve causes part *k* to close port *g*, and cavity *i* to connect ports *h* and *f*. The steam from chamber *B* then exhausts through port *h*, cavity *i*, in the reversing valve, and port *f* to the exhaust. The steam pressure in chamber *A*, acting on the inside area of the piston *77*, again moves the main-valve piston *76* to the right, taking the slide valve *83* with it, permitting steam to pass underneath piston *65* and force it upwards. What occurs during the upward stroke has already been explained. It will be noted in Fig. 21 that port *h* enters chamber *B* in such a way that piston *77* closes it before completing the stroke to the right. This arrangement permits of the piston being cushioned by any steam remaining in chamber *B* during the latter part of its movement to the right.

72. Operation of Air Cylinder.—When the air piston *66* makes an upward stroke, Fig. 21, it causes a partial vacuum to be formed below it while the air above is compressed. The air pressure below piston *66* and on top of the inlet valve *86′*, therefore becomes less than that of the atmosphere in passage *F* underneath this valve. Air then flows in through the screened inlet *W*, and passes downward through the passage *F*, unseats the inlet valve *86′* and passes through the ports in the valve cage and port *n* into the lower end of the air cylinder as shown by the arrows, filling it with air at atmospheric pressure. In the meantime, the air that is compressed above the piston holds the upper inlet valve *86* on its seat as the air pressure is now on top of the valve, and passes out through port *r* to the under side of the discharge valve *87*. As soon as the pressure in the upper end of the air cylinder exceeds that in the main reservoir, valve *87* raises

and the air flows through the passage *G* and out at *Z* to the main reservoir, as shown by the arrows. On the downward stroke of the air piston, Fig. 22, a partial vacuum is formed above, and the air is compressed below it, and the main-reservoir pressure on top of the upper discharge valve *87* holds it to its seat. Air then flows in through *W*, and goes up passage *F*, past the inlet valve *86*, through port *m*, and fills the upper part of the cylinder with air at atmospheric pressure.

As the air is compressed below the piston, it holds inlet valve *86′* on its seat, and passes through port *p* to the under side of discharge valve *87′*, and, as soon as the compressed air exerts a pressure slightly greater than that in the main reservoir, it opens valve *87′* and goes through passage *G* and out at *Z* to the main reservoir.

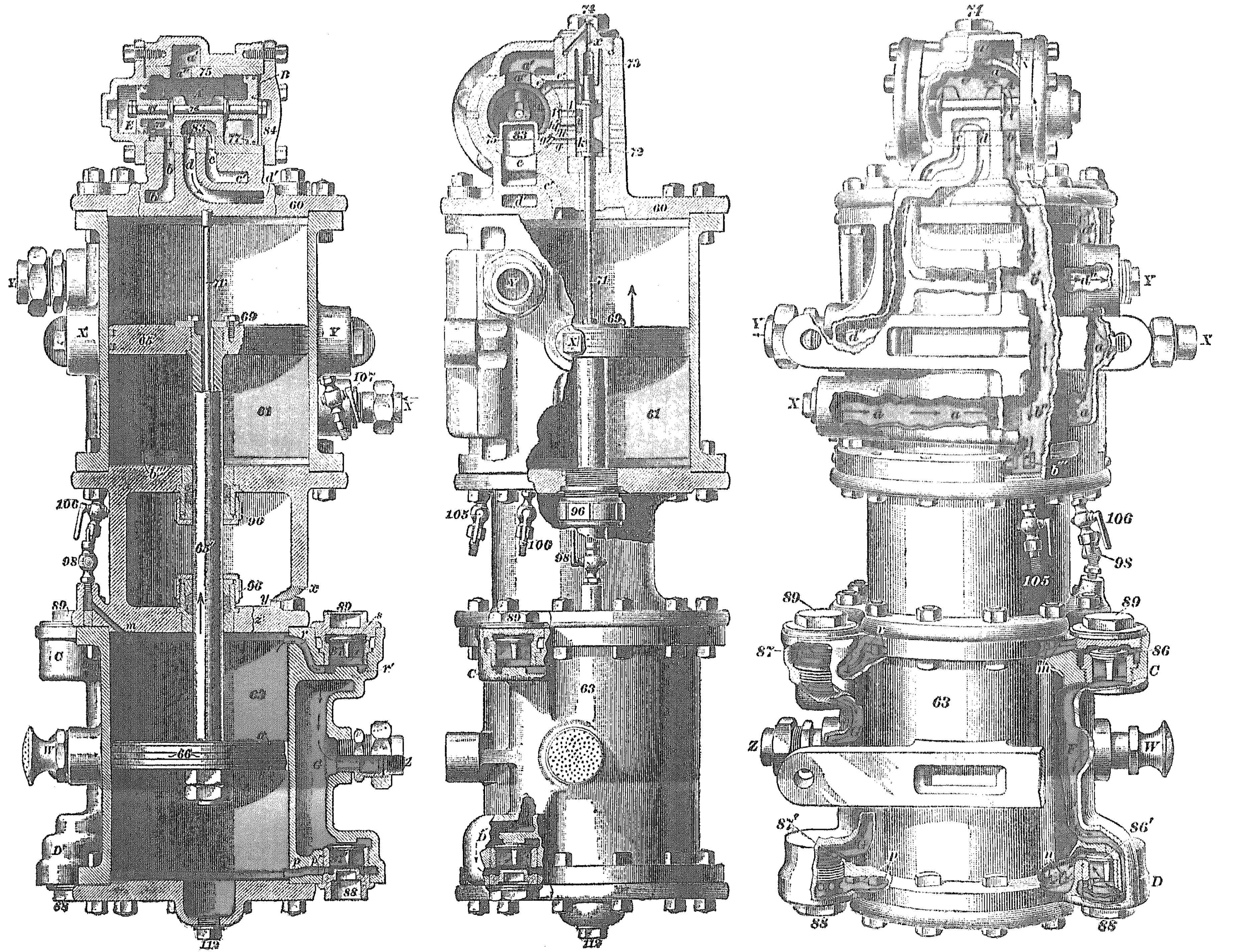
THE 11″×11″×12″ AIR COMPRESSOR

73. The 11-inch compressor was designed to meet the demand for a compressor of greater capacity than the 9½-inch. As the title implies, the diameter of the steam and air cylinders is 11 inches and the stroke is 12 inches. Two 11-inch compressors are usually installed on locomotives when the requirements for compressed air are beyond the capacity of a single compressor.

It will be noted, in Fig. 23, that the air cylinder and the arrangement of the valves are exactly the same as in the 9½-inch compressor with the exception of their size. All the ports, passages, and valves are made enough larger than those of the 9½-inch compressor to do the work properly for the larger capacity.

There are some differences in the position and arrangement of the steam passage in the walls of the steam cylinder and in the top head, as the steam enters the main-valve bush in front instead of at the back.

In Fig. 23, view (*a*) is a cross-section showing the front half of the compressor, and an additional portion of the centerpiece and air cylinder *x y z* is also shown broken away, so that a view of the discharge valve, discharge-valve cage and inlet-valve



60
61
63
65
66
69
71
72
73
75
84
86
87
88
89
96
98
105
106
107
112
C
D
W
X
Y
Z

(a) (b) (c)

FIG. 23

seat, and air passage *G* may be presented. In (*b*) is a side view, showing a section through the valve arrangement in the top head; a portion of the steam cylinder, also, is shown broken away. In (*c*) is a back view, in which portions of the steam and air passages and of the air-valve cages and seats are broken away to give a clearer idea of the location of the valves, ports, and passages. The steam-supply pipe is connected at *X*, and as this compressor has right- and left-hand connections, the steam and exhaust passages are double, view (*c*) showing these passages. The 9½-inch compressor, except earlier makes, is also right- and left-hand. Steam enters at the right-hand connection *X*, if the compressor is located on the engineer's side of the engine, or at the left-hand connection *X*, if on the fireman's side. It passes up through *a*, *a′* across the upper part of the top head, alongside the reversing-valve-chamber bush and in front of the main-valve bush, entering through the port *a″* between the two pistons *77* and *79* and around the main slide valve *83*. Steam also passes through port *e* and *e′* into the reversing-valve bushing *73* as in the 9½-inch compressor.

The operation of the 11-inch compressor, both steam and air ends, is precisely like that of the 9½-inch. There are three drain cocks in the steam and exhaust passages in the wall of the cylinder, in order to drain all the water out of the pockets formed by the passages that are not used.

As to the relative capacities of the 9½-inch and 11-inch compressors, the 9½ will compress 49 cubic feet of free air at 120 strokes per minute, and the 11-inch compressor will compress 66 cubic feet of free air at 100 strokes per minute against 100 pounds pressure.

THE 8½-INCH 150 CROSS-COMPOUND AIR COMPRESSOR

74. The number 150 in the name of the compressor refers to the volume of air in cubic feet per minute that it is capable of compressing when making 131 strokes per minute against a main-reservoir pressure of 140 pounds with steam pressure of 200 pounds.

The $8\frac{1}{2}$-inch cross-compound air compressor was introduced to meet conditions arising from the development of locomotives of greater weight and tractive power hauling longer trains with cars of greater capacity. Increasing the length of trains also increases the number of flexible connections and fittings where leakage may occur, and cars of greater capacity require auxiliary reservoirs and brake cylinders of greater volume. The necessity of applying many pneumatically operated auxiliary appliances, such as power reverse gears, air-operated fire-doors, etc., to large modern locomotives, also requires a compressor of greater capacity. The need of a quick recharge of the brake pipe and auxiliary reservoirs when descending heavy grades, in order to obtain maximum brake efficiency, as well as the prompt charging of long trains at terminals in order to avoid delay, also require a compressor of large capacity.

75. General Description.—The $8\frac{1}{2}$-inch cross-compound compressor may be compared to a $9\frac{1}{2}$-inch or 11-inch compressor with an additional steam cylinder and air cylinder. The steam, instead of being exhausted to the atmosphere after moving the steam piston, is exhausted to and operates a piston in another steam cylinder, the same steam being therefore used twice, or *compounded.* Because the steam is now at a lower pressure, this cylinder is called the *low-pressure steam cylinder,* the cylinder in which the steam is first used being called the *high-pressure steam cylinder.* The air from the air cylinder, instead of being discharged to the main reservoir direct, is discharged at a comparatively low pressure to another air cylinder called the *high-pressure air cylinder,* in which it is further compressed by an air piston connected by a piston rod to a piston in the low-pressure steam cylinder. The cylinder in which the air is first compressed is called the *low-pressure air cylinder.* The $8\frac{1}{2}$-inch compressor is then a two-stage compressor, the air being first drawn in and compressed in the low-pressure air cylinder by the operation of the high-pressure steam cylinder, and then compressed in the high-pressure air cylinder and discharged to the main reservoir by the action of steam in the low-pressure steam cylinder.

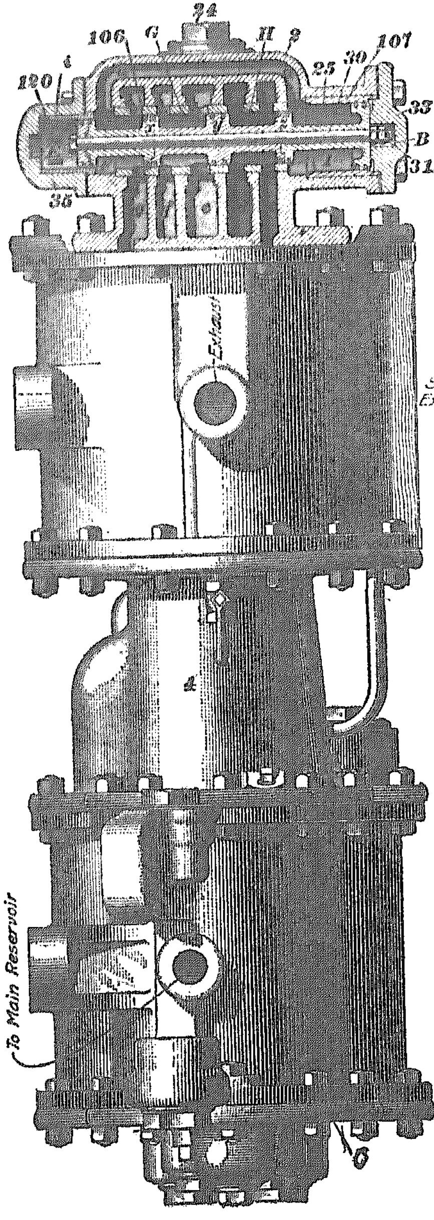

Exhaust
To Main Reservoir

Fig. 26

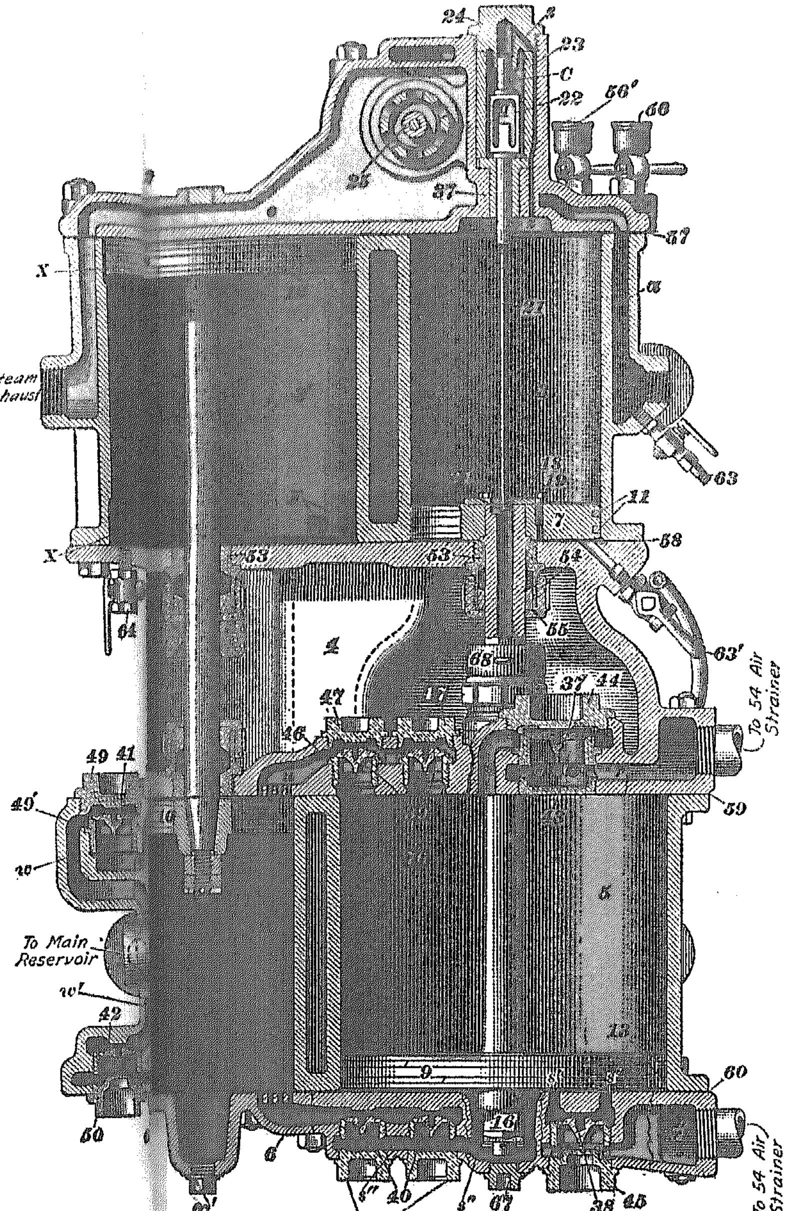

Steam Exhaust
To Main Reservoir
To 54 Air Strainer
To 54 Air Strainer

Fig. 27

As two steam cylinders are used, thus requiring the use of additional ports, the main valve directly concerned with the distribution of steam to and from these cylinders must necessarily be of different design from the main valve used with former types of compressors. However, the reversing-valve arrangement which controls the movement of the main valve is the same as is used with the 9½-inch and the 11-inch compressors.

76. Views of Compressor.—Figs. 24 and 25 show photographic reproductions of the 8½-inch cross-compound compressor viewed from opposite sides. Fig. 27 is a sectional view of the compressor showing the steam and air cylinders and the pistons that operate within them. Fig. 26 shows a view of the compressor with the upper portion sectioned, and Fig. 28 is a sectional view of the reversing-valve chamber. Figs. 29 and 30 are conventional views of the compressor showing the movable parts and ports in one plane. These two latter views are given as a means of assisting in explaining the operation of the compressor.

77. Description.—The 8½-inch cross-compound compressor as illustrated in Fig. 27 consists of four principal parts: the top head *2*; the steam cylinders *3* and *3'*, cast in one piece, the former being the high-pressure and the latter the low-pressure; the centerpiece *4* by which the steam and air portions are connected; and the air cylinders *5* and *5'*, cast in one piece, the former being the low-pressure and the latter the high-pressure. A copper gasket *57* is placed between the top head and the steam cylinders, a copper gasket *58* is placed between the steam cylinders and the centerpiece, and copper gaskets *59* and *60* are placed at the upper and the lower ends of the air cylinders. The high-pressure steam cylinder *3* is located above the low-pressure air cylinder *5*, the steam and air pistons being connected to the same piston rod; the high-pressure steam piston thus operates the low-pressure air piston. The low-pressure steam cylinder *3'* is placed above the high-pressure air cylinder *5'*, the high-pressure air piston *10* being operated by the low-pressure steam piston *8*, as both

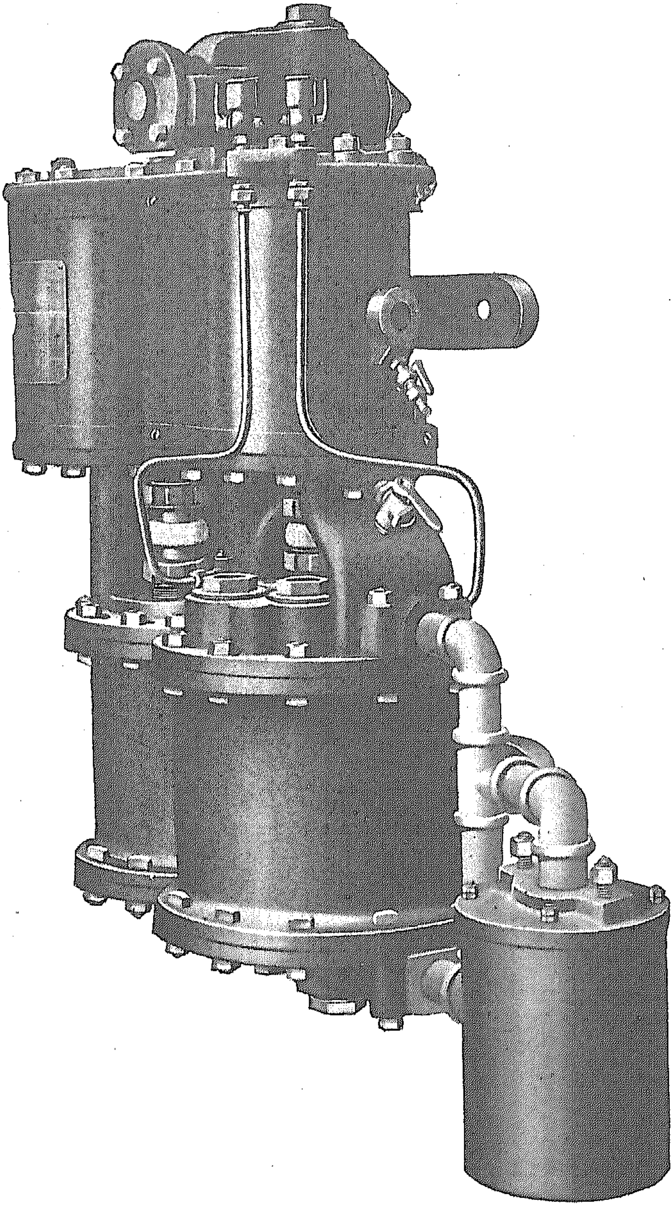


Fig. 24

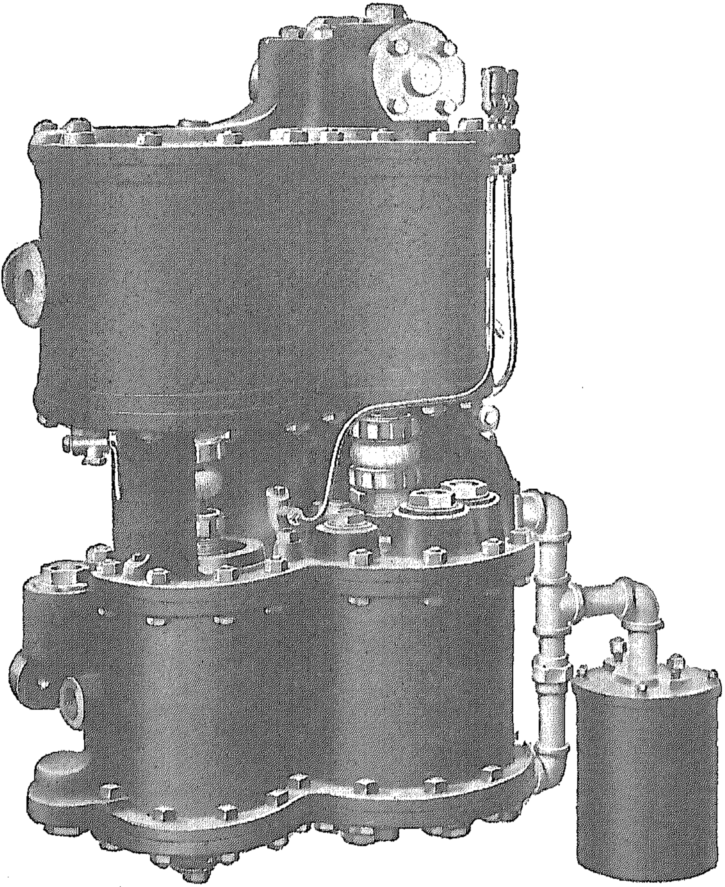


FIG. 25

pistons are attached to the same piston rod. The piston rods are screwed into the steam pistons, and the air pistons are secured to their piston rods by piston-rod nuts *15* and jam nuts *17*, the rods being tapered where they pass through the pistons.

The high-pressure steam cylinder is 8½ inches in diameter, the low-pressure steam cylinder is 14½ inches, the low-pressure air cylinder 14½ inches, and the high-pressure air cylinder is 9 inches. The piston in each cylinder has a 12-inch stroke.

78. Top Head.—The top head *2*, Figs. 26 and 27, which serves as a cylinder head for the high- and the low-pressure steam cylinders, contains the piston valve *25*, the function of which is so to distribute steam to the steam cylinders as to keep the pistons operating. The top head also contains the reversing valve *22* and the upper end of the reversing rod *21*, and the operation of these parts controls the movement of piston valve *25*. The piston valve *25* and reversing valve *22*, like the corresponding parts in the 9½-inch compressor, are so placed in the top head that both cannot be shown in the same sectional view. The top head *2* is fastened to the steam cylinders by T-head bolts and nuts.

79. Steam-Port Arrangement.—The actual arrangement of the steam ports in the top head for the steam cylinders of the compressor is shown in Fig. 26, but the connections of the various ports and passages can be more plainly seen in the diagrams, Figs. 29 and 30. The 9½-inch and 11-inch compressors require three ports to distribute steam to the steam cylinder and from the steam cylinder to the exhaust, but as one more steam cylinder is used with the 8½-inch compressor, two additional steam ports must be employed for the low-pressure steam cylinder, making five in all. It is not necessary to provide a separate exhaust port for this cylinder, as a common exhaust port is employed for both cylinders. The ports in the top head and the ends of the steam cylinders to which they connect are as follows: Port *c* leads through the top head to the top of the high-pressure cylinder, port *g* leads to the bottom of the high-pressure cylinder, port *d* leads

to the top of the low-pressure cylinder, port *f* leads to the bottom of the low-pressure cylinder, and port *e* is the common exhaust port for both cylinders. Ports *c, d, e, f,* and *g* connect at their upper ends to corresponding ports around the piston-valve bush *106*. Ports *c, d, f,* and *g*, like the ports in the ordinary steam engine, serve as steam ports when the steam pistons are moving away from them, and as exhaust ports when the pistons are moving toward them.

80. Piston Valve and Bushes.—The function of the piston valve *25*, Fig. 26, is to admit steam to each end of the high-pressure steam cylinder and exhaust the steam from each end of this steam cylinder to the corresponding end of the low-pressure steam cylinder, and finally exhaust the steam from each end of this latter cylinder to the atmosphere, the distribution of steam being such as to cause the steam pistons to move in opposite directions. In order to perform the above functions, the piston valve *25* must be of special design.

The two outer pistons are of unequal diameters, the larger one being at the right. These pistons may be termed the actuating pistons, as they control the movement of piston valve *25*, and may be compared to pistons *77* and *79* of the 9½-inch compressor. Pistons *x*, *y*, and *z* serve to make the proper divisions between the steam ports when the compressor is operating. The piston valve *25* then consists of five pistons, a large piston at one end, a small piston at the other end, and three intermediate pistons *x*, *y*, and *z*. The piston valve is made in three parts or sections, which are held together by a piston-valve bolt *30* and nuts. Each piston of the piston valve is provided with two packing rings so as to prevent steam from leaking past them.

The piston valve *25* operates within three bushes *106*, *107*, and *120*. Bush *106* contains a series of circular ports *c, d, e, f,* and *g* cut through the bush and extending around it, which register with corresponding ports in the top head, these ports in the top head extending completely around the bush. The ports in the top head, as already explained, lead to the different ends of the steam cylinders and to the exhaust. Bush *120* con-

tains six elongated grooves *i*, three of which are shown in Fig. 26, and also an exhaust port *o*, Fig. 28.

Bush *107*, as with the $9\frac{1}{2}$-inch compressor, contains port *m'* and *n'*, Fig. 28, which in connection with grooves *m* and *n* in the top head serve to connect the interior of the reversing-valve-chamber bush *23* with chamber *B*, Fig. 26. The pistons on the piston valve *25*, Fig. 26, in connection with the piston-valve cylinder heads *33* and *35*, form six chambers *E*, *F*, *G*, *H*, *I*, and *B*. Chambers *F* and *I* always contain live steam when the compressor is operating, as they are directly connected to the steam-inlet passage *a* in the top head. Cham-

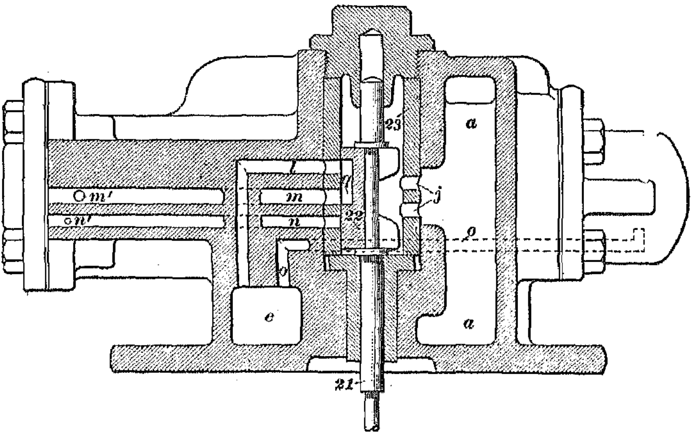
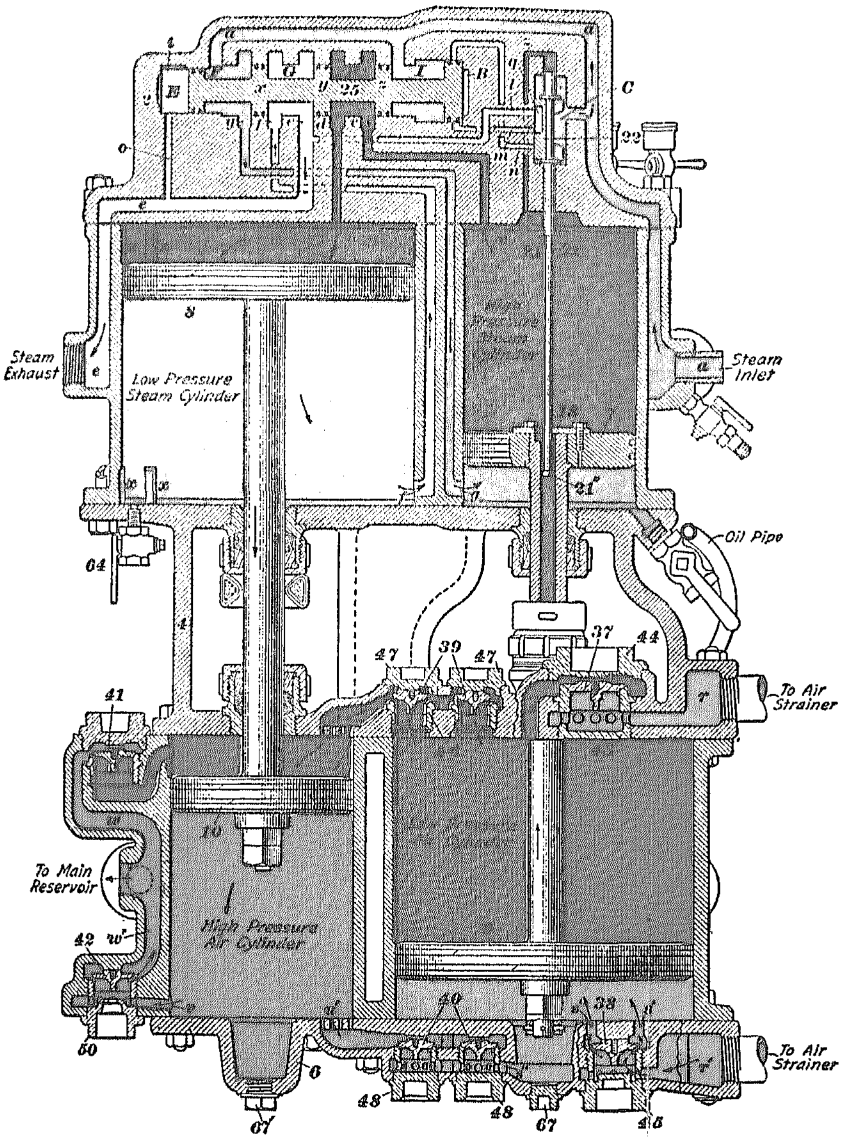


FIG. 28

ber *F* serves as a source of steam supply for the bottom of the high-pressure steam cylinder, and chamber *I* serves the same purpose for the top of the high-pressure steam cylinder, the port connections from these chambers to the opposite ends of the high-pressure steam cylinder being alternately opened and closed by piston valve *25*.

Chamber *H*, the space in the bush between piston *y* and *z*, makes the connection between the top of the high-pressure cylinder and the top of the low-pressure cylinder when the high-pressure steam piston is moving up, and connects the top of the low-pressure cylinder to the exhaust when the piston in this cylinder is moving up.



BB 514B 1957

Fig. 29

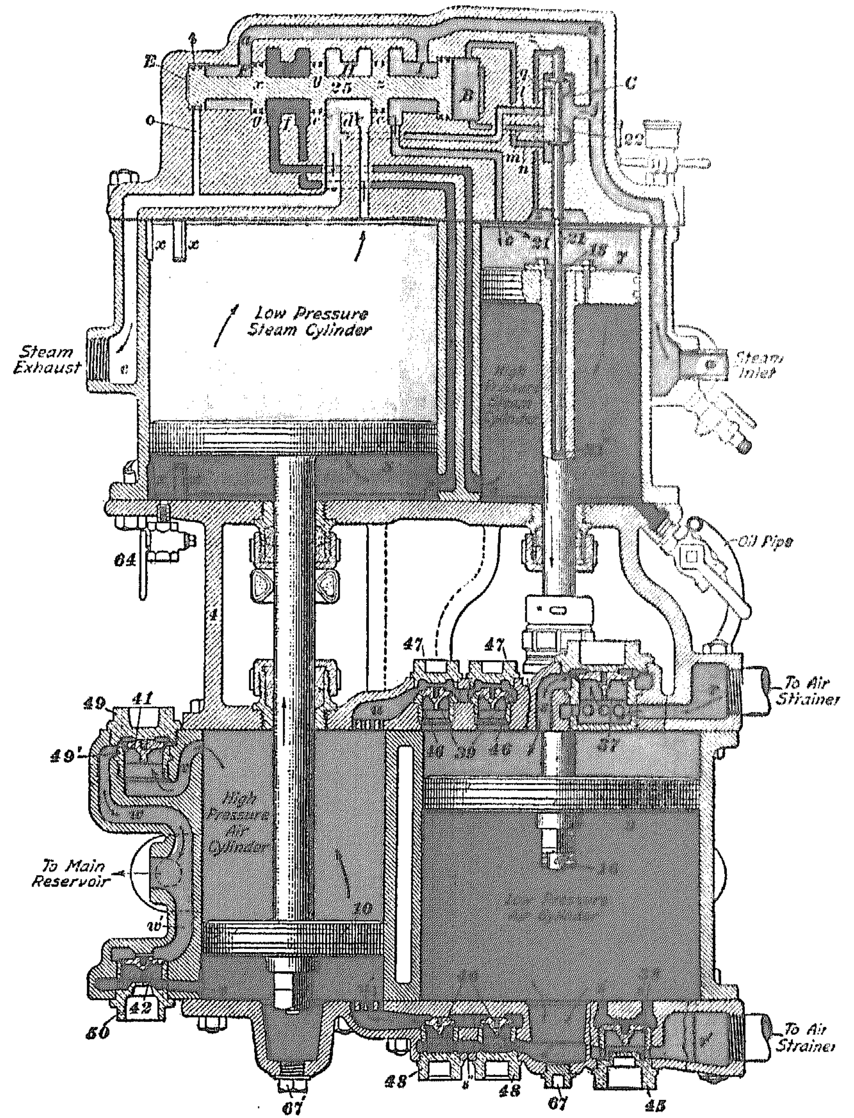


Fig. 30

Chamber *G*, the space in the bush between pistons *x* and *y*, performs the same function for the opposite or lower ends of the steam cylinders when the pistons are moving in the opposite direction, as it connects the lower end of the high-pressure steam cylinder to the lower end of the low-pressure steam cylinder, when the high-pressure steam piston is moving down, and the lower end of the low-pressure cylinder to the exhaust when the low-pressure piston is moving down.

Chamber *B*, as with the 9½-inch compressor, is alternately connected to live steam or to the exhaust by the reversing valve, the result of which is to cause the reverse movement of piston valve *25*. The port arrangement in chamber *E*, as will be explained under *Operation*, serves to cushion the piston valve in its movement to the left.

81. Reversing Valve and Bushes.—The reversing slide valve *22*, Fig. 28, which is operated by the movement of the high-pressure steam piston through the medium of the reversing rod *21* and the reversing plate, in the same manner as in the 9½-inch compressor, controls the flow of steam into and out of chamber *B*, Fig. 26. This valve causes the piston valve *25* to operate for the same reason as already explained when considering the 9½-inch and 11-inch air compressors. The port arrangement necessary to connect the reversing-valve-chamber bush *23* with chamber *B* is practically the same as with the 9½-inch compressor, except that ports *l*, *m*, and *n* are drilled in the top head instead of being in the main-valve bush as with the above compressor. Ports *n* and *n'* serve to admit steam from the reversing-valve-chamber bush to chamber *B*, ports *m'* and *m* convey the steam away from chamber *B*, and in the lower position of the reversing valve as shown delivers it to port *l*, which is an exhaust port and connects to the exhaust passage *e*. Port *m'* is so located in the bush that it is closed by the large piston of piston valve *25*, before the piston completes its stroke to the right. This provides a cushioning effect for valve *25*, by entrapping some steam in chamber *B* after the large piston of the valve has moved past it. Passage *o* connects chamber *E*, Fig. 29, with the exhaust port *e*.

The reversing-valve bush *23*, Fig. 28, is kept supplied with live steam from steam passage *a* through ports *j*. No reversing arrangement is required for the low-pressure steam cylinder, as the piston valve when it moves to reverse the high-pressure piston also causes a distribution of steam that results in the reversal of the low-pressure steam piston.

82. Description of the Air Cylinders.—The top head of the air cylinders *5* and *5′* of the 8½-inch compressor, as shown in Fig. 27, is formed by the bottom surface of the centerpiece *4*, and the bottom head of the air cylinders is formed by the part *6*. The compressor has ten air valves, eight of which are located in the low-pressure air cylinder and two in the high-pressure air cylinder. They are designated as follows: two upper inlet valves *37* (one being shown), two lower inlet valves *38* (one being shown), two upper intermediate valves *39*, two lower intermediate valves *40*, one upper discharge valve *41*, and one lower discharge valve *42*. The inlet and discharge valves are interchangeable. The air valves of the 11-inch compressor are also interchangeable with the inlet and discharge valves of this compressor. The air valves of the 9½-inch compressor are interchangeable with the intermediate valves. The upper inlet valve *37* operates between the bottom of the valve-chamber cap *44* and valve seat *43*, which is screwed into the centerpiece *4*. The lower face of the valve cap *44* has lugs which when the cap is screwed down engage with the valve seat *43* and prevent the seat from working up and reducing the lift of the inlet valves, and resembles the enlarged detail given in Fig. 17. The valve seat *43*, Fig. 27, contains a series of ports, as shown, which lead into passage *r* which in turn leads to the air inlet. Passage *s* leads from the top of the inlet valves *37* to the upper end of the low-pressure air cylinder. The upper end of the lower inlet-valve cage *45*, this cage being screwed into the bottom cylinder head forms a seat for the lower inlet valve *38*. Cage *45* contains a series of ports as shown which connect to passage *r′* and the air inlet. Passages *s′* lead from the top of inlet valves *38* to the lower end of the low-pressure air cylinder.

83. The upper intermediate valves *39* operate between the bottom of the valve-chamber caps *47* and valve seats *46*, which are screwed into the centerpiece *4*. The lower faces of the valve caps *47* have lugs similar to the valve caps *44*, which prevent the valve seats from working upward. The lugs are not shown in contact with the valve seats in Fig. 27, as if shown they would obstruct a view of the air passage *u*. As the intermediate valves, unlike the inlet valves, open directly into the air cylinder, perforated guard plates *76* are placed under the lower end of the valve seats as shown, and serve to prevent a portion of a broken valve or seat from falling into the air cylinder. Passage *u* connects the top of the upper intermediate valves to the upper end of the high-pressure air cylinder. The lower intermediate valve cages *48* are screwed into passage *u′* in the lower cylinder head *6*, and their upper ends form seats for the lower intermediate valves *40*. The cages *48* contain a series of circular ports as shown which connect to the lower end of the low-pressure air cylinder through passage *s″*. The upper faces of the intermediate valves are connected by passage *u′* to the lower end of the high-pressure air cylinder. The upper discharge valve *41* operates between the top of the valve seat *49′* and the lower face of discharge-valve cap *49*. The valve seat *49′* is screwed into a projection on the high-pressure air cylinder. Lugs on the valve cap prevent the valve seat from working upwards when they are screwed down tight.

Passage *v* connects the upper end of the high-pressure air cylinder to the lower face of the upper discharge valve, and passage *w* extends from the upper face of the discharge valve *41* to the main-reservoir connection. The upper end of the lower valve cage *50* forms a seat for the lower discharge valve *42*, and the cage is screwed into a projection on the high-pressure air cylinder. A series of ports in cage *50* in connection with passage *v′* serves to connect the lower end of the high-pressure air cylinder to the lower face of the discharge valve *42*. Passage *w′* connects the upper face of the discharge valve to the main reservoir. All the air valves in the bottom head when unseated strike a boss, or stop, above them, which deter-

mines their lift. Similar bosses are provided on the valve caps *44*, *47*, and *49*. All air valves have a lift of $\frac{3}{32}$ inch. Plug *67* when removed gives a means of raising the air piston when desired to remove the reversing rod. It can also be determined if the nuts *16* on the lower end of the rod are working off and whether air is leaking from the high- to the low-pressure air cylinder by the intermediate valves when plug *67* is removed. Plug *67'* when removed gives a means of determining whether the nuts on the high-pressure air piston are working loose and whether there is any leakage from the main reservoir to the high-pressure air cylinder.

84. Air-Cylinder Lubricators and Drain Arrangement.—The air-cylinder lubricators are shown in Fig. 27 in which *56* is the lubricator for the low-pressure air cylinder, and *56'* the one for the high-pressure air cylinder. The lubricators, which are fastened to the top head by a bracket, are connected by oil pipes to the air cylinders, the oil being fed from the lubricators to the oil pipes by opening cocks by the handles shown.

Fig. 31 (*a*), which is a view of the top head of the air cylinders, shows where the oil pipes connect, the oil pipe to the low-pressure air cylinder being connected at *a* and that to the high-pressure air cylinder at *b*.

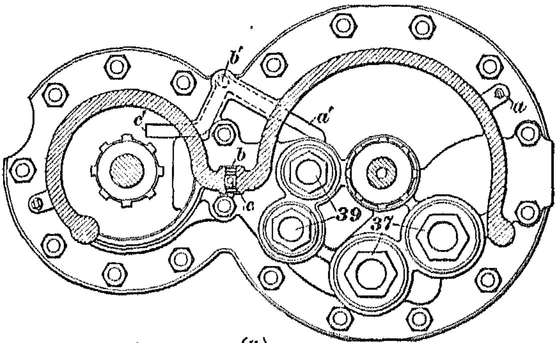
Port *b* is located so that oil will feed directly into the inlet passage *u*, Fig. 27, leading to the high-pressure air cylinder. The top head is tapped for a $\frac{3}{8}$-inch pipe on both the front and back of the rear wall, thus permitting the oil pipe, or oil cup or cock to be attached at either the front or back, the opening not in use being plugged as shown. The small hole *c* normally closed by a plug permits of the oil passage being cleaned out.

Fig. 31 (*a*) shows the arrangement to take care of the water that may drip from the stuffingboxes. The water is drained through passages *a'* and *c'* to *b'*, views (*a*) and (*b*), and from thence by means of a pipe to some convenient point.

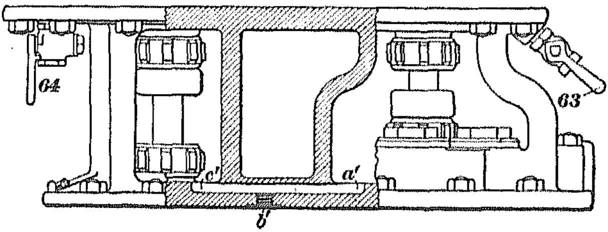
85. Drain Cocks.—The $8\frac{1}{2}$-inch compressor is provided with three drain cocks. Drain cock *63* is used to drain the steam passage *a*, Fig. 27. Cock *63'* is employed for the high-

pressure steam cylinder, and cock *64* is used for the low-pressure steam cylinder. All drain cocks should be opened for a short time when starting the compressor.

86. Operation of Steam Cylinders.—When steam is shut off from the compressor, the high- and the low-pressure pistons *7* and *8*, Figs. 29 and 30, naturally settle to the lower end of their cylinders, and in so doing the reversing plate *18*, Fig. 29, on the high-pressure steam piston engages the button



(a)



(b)

FIG. 31

21'' on the end of the reversing-valve rod *21* and pulls the reversing valve *22* down into its lower position. As soon as steam is admitted to the compressor at the steam inlet *a*, it passes through port *j* into the reversing-valve chamber *C* and then through passage *a* to chambers *I* and *F*, which serve as steam chests for the upper and lower ends of the high-pressure steam cylinder. In this position of the reversing valve, chamber *B* is connected to the exhaust through port *m*, cavity *q* in

the reversing valve, and ports *l* and *c*. The main piston valve *25* will move to the extreme right, as shown in Fig. 29, as soon as steam is admitted to the compressor, because the area of the piston on the extreme right is the larger and its inside surface in chamber *I* is subjected to the same pressure per square inch as is the inside surface of the smaller piston in chamber *F*. When the valve *25* is in this position, steam from chamber *F* can pass through port *g* to the lower end of the high-pressure steam cylinder and thus force the high-pressure steam piston *7* upwards. The upper end of this cylinder will then be connected to the upper end of the low-pressure steam cylinder through port *c*, chamber *H*, and port *d*; also, the lower end of the low-pressure steam cylinder will be connected to the exhaust through port *f*, chamber *G*, and port *e*. As the high-pressure steam piston completes its up stroke, the reversing plate *18* strikes the shoulder *21′* on the reversing rod *21* and moves the reversing valve *22* to its upper position shown in Fig. 30. This movement blanks port *m* and uncovers port *n* so that steam can enter chamber *B* and thus nearly balance the pressure on both sides of the large piston of the main piston valve *25*. This allows the pressure in chamber *F* acting on the inner face of the small piston to move the piston valve *25* to the left, as shown in Fig. 30, as chamber *E* before the valve moves is connected to the exhaust through port *o*. When the piston valve *25* is in this position, live steam from chamber *I* can pass through port *c* to the top end of the high-pressure cylinder above piston *7*. The steam from underneath the high-pressure steam piston *7* can pass to the under side of the low-pressure steam piston *8* by way of port *g*, chamber *G*, and port *f*, forcing the low-pressure steam piston *8* upwards. The upper end of the low-pressure steam cylinder is connected to the exhaust through port *d*, chamber *H*, and port *e*.

As the high-pressure steam piston almost completes its down stroke, the under side of the reversing plate *18* engages the button *21″* on the end of the reversing rod *21* and pulls the reversing rod and valve down to the lower position as shown in Fig. 29.

In this position port *n* is closed and ports *l* and *m* are connected by cavity *q* in the reversing valve and the steam in chamber *B* is exhausted into exhaust port *e*. The steam in chamber *I* then forces the piston valve *25* to the right, opens port *g* and permits steam from chamber *F* to flow to the lower end of the high-pressure steam cylinder and force the piston upwards. The steam exhausting from above the high-pressure steam piston can pass through port *c*, chamber *H*, and port *d* to the upper end of the low-pressure steam cylinder and thus force piston *8* down and the steam below this piston escapes through port *f*, chamber *G*, and exhaust port *e*. When the compressor is first started, the high-pressure steam piston may make several strokes before sufficient pressure accumulates in the low-pressure cylinder to move the low-pressure piston. If the steam rings on the low-pressure piston are in good condition, and the compressor is warm, one stroke of the high-pressure piston should be sufficient to start the low-pressure piston; if the rings are not tight or if the compressor is cold, several strokes of the high-pressure piston may be required.

87. By-Pass Grooves.—There are three by-pass grooves in each end of the low-pressure steam cylinder. When the compressor is operating, the steam pressure in the low-pressure cylinder, in addition to moving the low-pressure steam piston, also acts as back pressure against the high-pressure steam piston. The object of the by-pass grooves is to relieve this back pressure just before the high-pressure steam piston completes either stroke by connecting one end of the low-pressure cylinder and therefore the same end of the high-pressure cylinder to the atmosphere.

The relieving of pressure from the high-pressure piston at this time insures that the piston will move sufficiently to operate the reversing rod and valve and thus reverse the compressor. The high-pressure steam piston is under its greatest load as it nears the end of its stroke, because the pressure in the low-pressure air cylinder is at its maximum. Therefore, in order to insure the high-pressure piston completing its stroke and thereby reversing, it is necessary to provide by-pass grooves

in the low-pressure steam cylinders. Assume, as in Fig. 29, the high-pressure piston to be moving upwards and the low-pressure piston moving downwards. Just before the two pistons complete their stroke, the by-pass grooves in the lower end of the low-pressure cylinder connect the upper end of the low-pressure cylinder, and therefore the upper end of the *high-pressure cylinder, with the lower end of the low-pressure* cylinder which is now connected by the piston valve *25* to port *f* and the exhaust port *e*. This temporary relief of back pressure on the upper side of the high-pressure piston insures its completing its upward stroke. The small piston-valve cylinder head is provided with a bush having six elongated grooves *i*, three shown. As the main valve moves toward the left and uncovers these grooves, live steam from chamber *F* by-passes to chamber *E* back of the small end of the piston. At the instant the grooves are cut off by the further movement of the piston, port *o* leading to the exhaust is also blanked so that the small piston compresses the steam in chamber *E* and is thereby cushioned. Port *z* serves the same purpose as port *x*, Fig. 21.

88. Operation of the Air Cylinders.—The 8½-inch compressor is a two-stage compressor. Air is first drawn into the large low-pressure air cylinder and then discharged to the smaller high-pressure air cylinder, this operation resulting in the air being raised to a pressure of 40 pounds to the square inch in the high-pressure air cylinder. This is the first stage of compression. The final compression is accomplished by the high-pressure air piston forcing the air into the main reservoir. Assume that both steam pistons are operating and that the high-pressure steam piston is beginning its upward stroke, as in Fig. 29. This in turn causes the low-pressure air piston *9* to move up because it is connected to piston *7* by means of the piston rod. As the low-pressure air piston *9* moves up, it causes a partial vacuum to be formed below it and at the same time compresses the air above it. The space under the inlet valves *38* is at all times filled with air from the atmosphere through the air strainer and the passage *r′*. The partial vacuum formed below the air piston *9* allows the

atmospheric pressure to raise the two lower inlet valves *38* and force air through the passages *s′* into the lower end of the low-pressure air cylinder; thus, the space below piston *9* is filled with air at atmospheric pressure. The air above piston *9*, which is being compressed, raises the two upper intermediate valves *39* and is forced through passage *u* to the upper end of the high-pressure air cylinder and assists the low-pressure steam piston *8* in moving the high-pressure air piston *10* down. The air under the high-pressure air piston, which is at a pressure of about 40 pounds to the square inch, is further compressed and forces the bottom intermediate valves *40* to their seats, and passing through port *v* unseats the lower discharge valve *42*, and flows through passage *w′* to the main reservoir. When the low-pressure air piston moves down, Fig. 30, it forms a partial vacuum above it and compresses the air below it. Air from the atmosphere entering through the air strainer and passage *r*, raises the two upper inlet valves *37*, and passing through passage *s*, fills the space above piston *9* with air at atmospheric pressure. The air below piston *9* is compressed, forces the lower inlet valves *38* to their seats, passes through passage *s″*, raises the two lower intermediate valves *40* and is forced through passage *u′* into the lower end of the high-pressure air cylinder. The air forced into the lower end of the high-pressure air cylinder exerts its force on the lower side of the high-pressure air piston *10*; also, it acts in conjunction with the steam in the lower end of the low-pressure steam cylinder in forcing up the steam piston *8* and air piston *10*. As piston *10* moves up, it compresses the air in the upper end of the high-pressure air cylinder, which is now at a pressure of about 40 pounds to the square inch, forcing the upper intermediate valves *39* to their seats, and passing through port *v* opens the upper discharge valve *41*. The air then enters the main reservoir through passage *w*.

The areas of the high-pressure steam piston and low-pressure air piston are such that the steam piston will operate against an air pressure of 40 pounds. With a boiler pressure of 200 pounds, the pressure in the high-pressure steam cylinder

will be about 190 pounds and the pressure in the low-pressure steam cylinder will be about 70 pounds, which acting as back pressure on the high-pressure piston leaves an effective pressure of 120 pounds to operate this piston. A pressure of about 40 pounds per square inch on the low-pressure air piston will then about balance a pressure of 120 pounds per square inch acting on the high-pressure steam piston. This explains why if the discharge valves leak and allow air to pass back from the main reservoir to the high-pressure cylinder, thereby holding the intermediate valves closed, the compressor will stop with a main-reservoir pressure of 40 pounds.

THE FIFTY-FOUR AIR STRAINER

89. Under certain climatic conditions, the old form of air strainer frequently clogged with snow or frost, resulting either in a low air pressure or an air failure. Holes were sometimes punched in the screen or the screen itself might be missing, or partially closed by an accumulation of gum, especially on the inside.

The heat evolved during the compression of air to the high main-reservoir pressure required demands constant lubrication to avoid rapid wear of piston rings and cylinder walls. Dust drawn in with the air destroys the lubrication, adds grit to the dry surfaces, and thereby increases wear. Hence, to overcome such conditions, the dust and dirt in the air must be prevented from entering the air cylinder, and the special Fifty-Four air strainer was designed to accomplish this. The name of the strainer is derived from its large suction area, which is 54 inches.

90. Construction of Strainer.—Two views of the strainer are given in Fig. 32, view (*a*) showing the strainer in section while view (*b*) shows it disassembled. It will be seen from view (*a*) that the strainer proper consists of an outer strainer *a* made of coarse galvanized wire mesh, and an inner strainer *b* made of perforated sheet steel, the two con-

nected by studs, and the space between the strainers *a* and *b* being well packed with curled hair. A galvanized-iron sheet *c* surrounding the strainers prevents dirt, water, or oil from striking them directly and lessens the possibility of clogging.

The pipe leading from the air passage in the compressor is connected to the head *d* of the strainer at *e*, view (*b*). The studs and nuts *f* are used to attach the strainer to any part of the engine that may be convenient, and so prevent vibration. The outer strainer *a*, which also includes strainer *b*, can be removed from the outer shell when necessary to renew the hair, by removing the nuts *g*, view (*a*), on the studs, after

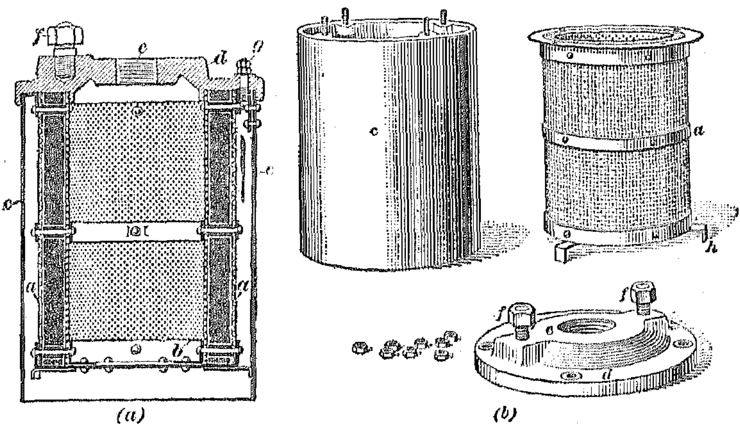


FIG. 32

which the shell *c* and the contained strainer can be removed by pulling downwards, leaving the head *d* attached to the compressor. The upper end of the strainer *b*, view (*b*), is flanged where it rests on the shell *c* while the lower end has projections *h* which hold the strainer in its proper position in shell *c*. When installing the strainer, it should be placed vertically with the opening downward and secured under the running board at some point where the cleanest and driest air is available. It should never be placed where a probable steam leak would saturate the air that is being drawn in.

91. Operation.—Air is drawn into the strainer, Fig. 32 (*a*), between the shell *c* and the outer strainer *a*, and

passing through screen *a*, the curled hair, and strainer *b* enters into the interior of the strainer. From there it passes up through passage *e* and thence through a pipe to the air inlet valves.

COMPRESSOR TESTS

92. Rules Governing Tests.—According to the Federal rule, it is to be understood that if the compressors are just able to meet the prescribed tests, they have reached the limit of their usefulness and must be repaired. Therefore the rule prescribes the condemning limits of the compressors and not their passing limits. The rule follows:

"The compressor or compressors shall be tested for capacity by orifice tests as often as conditions may require, but not less frequently than once in three months.

"The diameter of orifice, speed of compressor, and the air pressure to be maintained for compressors in common use are given in the following table:

Size of Compressor Inches	Single Strokes Per Minute	Diameter of Orifice Inches	Air Pressure Maintained Pounds
$9\frac{1}{2}$	120	$\frac{11}{64}$	60
11	100	$\frac{3}{16}$	60
$8\frac{1}{2}$	100	$\frac{9}{32}$	60

"This table shall be used for altitudes to and including 1,000 feet. For altitudes over 1,000 feet the speed of the compressor may be increased five single strokes per minute for each 1,000 feet increase in altitude."

93. Testing Device.—Fig. 33 shows three views of a testing device. View (*a*) is a disassembled view of the disk holder, which consists of the parts *a* and *a'*, orifice disk *b*, and gasket *c*. View (*b*) is a sectional view of parts shown in view (*a*) assembled, and view (*c*) shows the manner in which the disk holder is connected to the main reservoir.

To assemble the parts shown in view (*a*), the orifice disk *b*, having an orifice of a specified size, is placed first in the nut *a'*

and the gasket *c* is then inserted, after which the two parts *a* and *a′* are screwed together. In view (*b*) is shown a section through the disk holder when it is assembled, and in view (*c*) the disk holder is shown in place, the part *a* being screwed

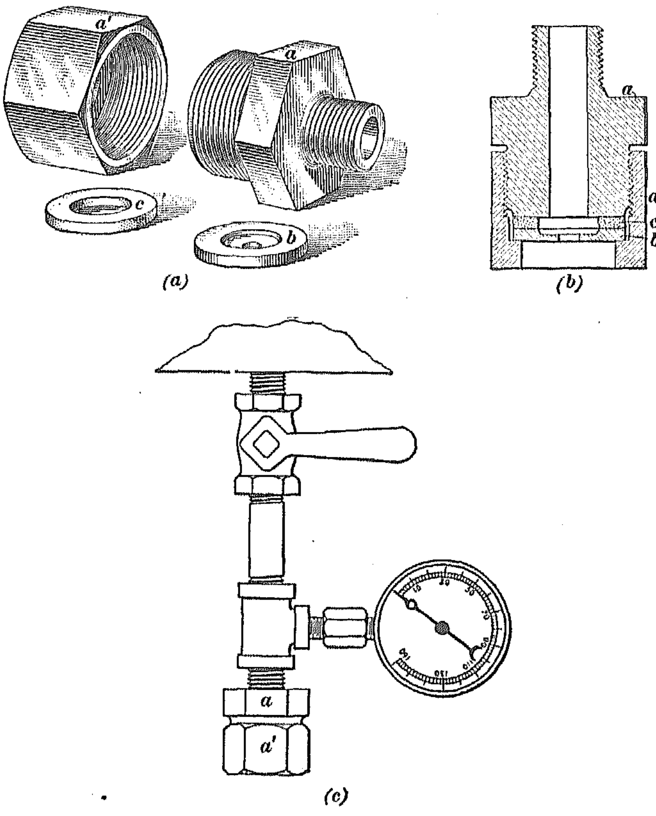


FIG. 33

into a ½-inch pipe that connects to the main-reservoir drain cock and also to an air gauge. In the pipe is also a cut-out cock, as shown.

94. Test for Leakage.—Before the compressor is tested, the main reservoir should be drained and it and the piping on the engine tested for leakage. Otherwise the test

would indicate a poorer condition of the compressor than is the case, due to extra labor required to maintain the leakage. The leakage test is made by closing the throttle to the compressor after obtaining the main-reservoir pressure corresponding to the governor setting. Then with the A-1 equipment, the double-heading cock should be closed, or if none is provided, the brake valve should be lapped.

With the No. 6 ET equipment, in addition to the above, the cut-out cock in the supply pipe to the distributing valve must be closed. After this is done, the main-reservoir pressure should be drained down to about 60 pounds. The gauge on the engine should then be watched, and the fall in pressure from 60 pounds noted. Leakage in excess of 2 pounds per minute should be stopped for the reason above mentioned before beginning the test.

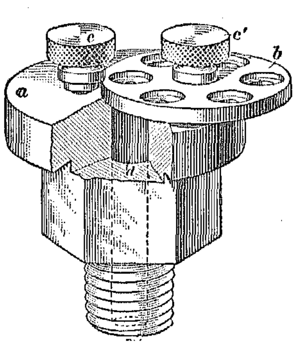


FIG. 34

95. Making the Test.—To make the test, the testing device assembled as shown in Fig. 33 (*c*) is connected to the main-reservoir drain cock. The compressor should then be started, and the cut-out cock in the testing device opened. The steam supply to the compressor should be throttled until the main-reservoir pressure is maintained at approximately 60 pounds. The stroke of the compressor should then be noted by counting the pump exhausts, each exhaust being a stroke. If the number of strokes are in excess of 120 per minute for the 9½-inch compressor, and 100 for the 11-inch and the 8½-inch compressors, when using the size of orifice opening specified, the compressor must be repaired.

Fig. 34 shows a view of a testing device with a part broken away, which differs somewhat from the one illustrated in Fig. 33 as the orifices necessary to test different types of compressors are all contained in one disk.

The device consists of a part *a*, the middle portion of which is hexagonal in shape while the lower portion has a

$\frac{1}{2}$-inch pipe thread, and a disk *b*, containing six different-sized orifices, secured to a part *a* by a thumbscrew *c'*. An opening *d* extends through part *a*. The orifice desired can be used by loosening thumbscrews *c*, *c'* sufficiently to permit disk *b* to be rotated about *c'* until the orifice of the proper size is over hole *d*, after which the thumbscrews are again screwed down tight. Disk *b* contains orifices of the prescribed size for the testing of the three types of the Westinghouse and the New York air compressors. The threaded portion of the testing device can be screwed into the main-reservoir drain cock when making the test or it can be secured to a coupling that permits of the device being connected to the brake-pipe hose instead of to the main reservoir if desired.

OPERATING A COMPRESSOR

96. Starting and Running the Compressor.—When starting the compressor, the drain cocks in the steam end, if not already open, should be opened. The compressor should first be run slowly until all the condensed steam has escaped through the drain cocks, and until a main-reservoir pressure of 25 or 30 pounds has been reached. This pressure provides an air cushion for the piston, and is necessary to prevent the piston from striking the cylinder head on account of the small amount of clearance provided, which would cause pounding and loosen the air piston on the rod. When sufficient air cushion has been obtained, and all condensation has escaped, the drain cocks should be closed, and the compressor throttle opened to run the compressor at the required speed. Care must be taken not to run the compressor at an excessive rate of speed.

97. Stopping the Compressor.—To stop the compressor at the end of a trip, the lubricator to the steam cylinder should be closed off, then the steam valve, and all drain cocks on the compressor should be opened. The drain cock on the main reservoir should also be opened so as to allow all moisture to drain from the reservoir.

98. Lubrication of Steam Cylinder.—The steam-cylinder lubricator should not be started until the drain cocks have been closed, and the compressor is ready to be run at the required speed. The lubricator should then be started, and ten or fifteen drops of oil fed as rapidly as possible. After this is done the oil supply should be cut down to about one or two drops per minute for one compressor. The amount of oil required will depend on the speed at which the compressor is operating, its condition, etc. Therefore, no definite amount can be specified. A well-oiled swab is necessary on the piston rod to protect the rod packing.

99. Lubrication of Air Cylinder.—Although valve oil is almost universally used to lubricate the air cylinder of the compressor, yet it is not altogether suitable for this purpose. A heavy oil like valve oil will not atomize properly; also, it will tend to collect any dirt or cinders that may be in the air and the mixture then accumulates and obstructs particularly the inner ends of the passages to the air discharge valves, where it is hardened by the heat. This condition can be overcome to some extent by using the oil as sparingly as possible.

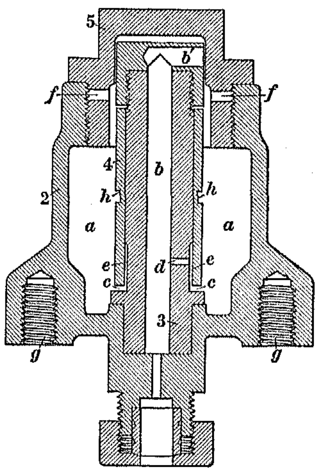


Fig. 35

100. Automatic Oil Cup. The automatic oil cup, Fig. 35, which shows a sectional view, is designed to feed the proper amount of oil to the air cylinder to which it is attached. These oil cups supersede the hand or non-automatic cups *56* and *56'*, Fig. 27.

The oil chamber *a* in the body *2* is filled from the top by removing the cap nut *5*. The vent hole *f* in the cap nut is so located that when the seal between the cap nut and the body is broken, the air pressure in the cup is vented to the atmosphere. The cap can then be fully removed and the cup filled, if necessary,

when the compressor is running. A central passage *b* in the stem *3* communicates at the bottom to the pipe leading to the air cylinder; at the top the passage has a side outlet *b'* that leads into chamber *a*. This outlet is on the side so as to prevent oil from being poured into passage *b* when filling the oil cup.

When the compressor makes an upward stroke, air is forced up through passage *b* above the oil in chamber *a*. The oil will flow through the notches *c* into the annular cavity *e* and thence through an oil port *d* of definite size to passage *b*. On the downward stroke of the piston, the small amount of oil that has been forced through port *d* is carried with the flow of the air from the chamber on top of the oil into the compressor cylinder.

Owing to the minute particles of oil supplied in uniform quantities to the air cylinder and to the fact that the oil cup operates only when the compressor is working, one filling of the oil chamber will supply sufficient lubrication for the average trip.

The stud holes *g* shown are used to secure the oil cup to its bracket, and the groove *h* is provided to assist in the removal of the sleeve *4* should it become stuck to the stem.

NEW 8½-INCH 150 COMPRESSOR

101. The 8½-inch cross-compound compressor already described is intended for use with steam pressures not exceeding 275 pounds. For higher pressures, different materials are used and changes have been made in the reversing valve, Fig. 36, and in the main valve, Fig. 37; also an additional steam connection is provided in the top head as at *a*, Fig. 36, here shown plugged. The steam inlet connection at *b* is provided for a 1¼-inch pipe and the exhaust connection at *c* is for a 1½-inch pipe. The air inlets are shown at *d* and these inlets are normally connected by a 2-inch pipe to a 54 air strainer. A 1½-inch discharge pipe is connected at *e*. The oil cups *f* are connected by pipes to the high- and the low-pressure air cylinders.

102. The new piston-type reversing valve shown in its up position in Fig. 38 (*a*) and in its down position in (*b*) performs the same function as the slide-valve type but is subject to less

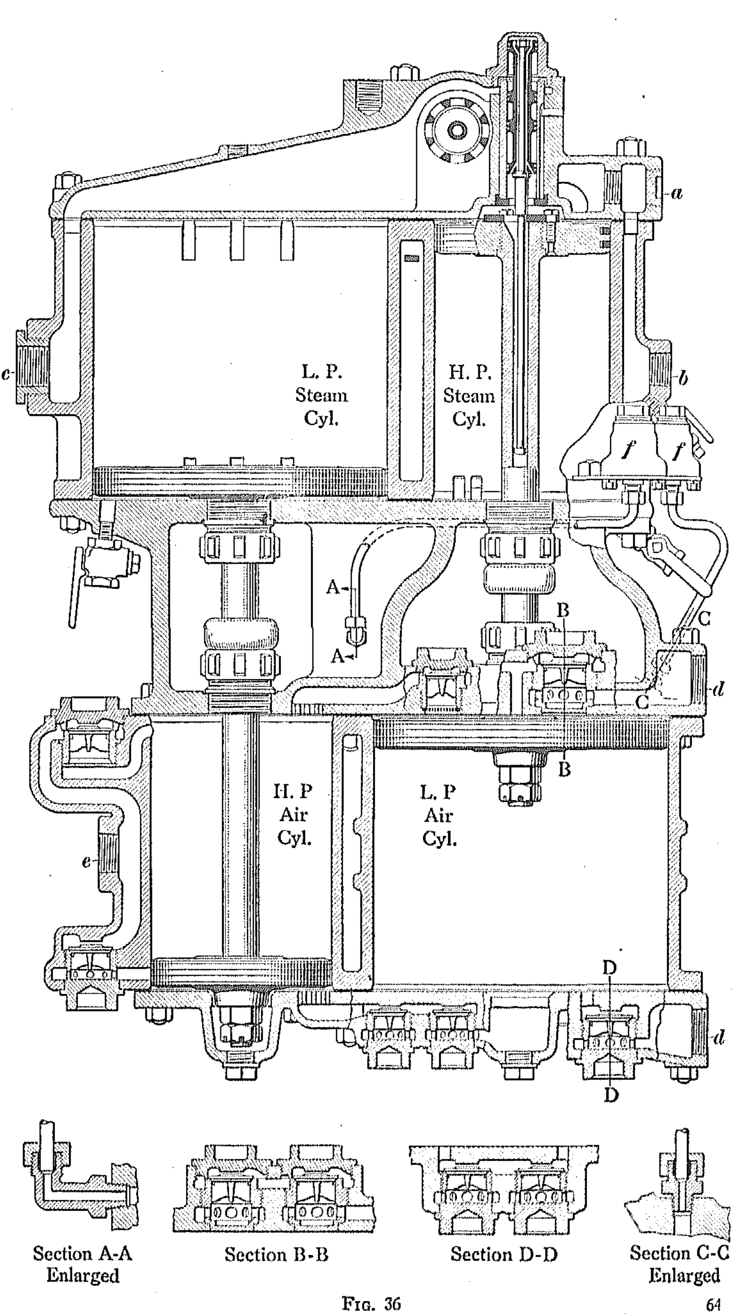

a
b
c
d
e
f
f
L. P.
Steam
Cyl.
H. P.
Steam
Cyl.
A
A
B
B
C
C
D
D
H. P
Air
Cyl.
L. P
Air
Cyl.
d
e
Section A-A
Enlarged
Section B-B
Section D-D
Section C-C
Enlarged

Fig. 36

friction, so that the strain on the reversing rod is reduced and better performance assured. The piston-type reversing valve is a multiple-piston device and consists of four pistons of the same

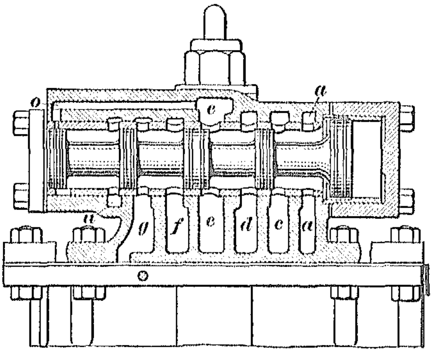


FIG. 37

size, except the upper piston, which is slightly smaller. A port z through the piston equalizes the pressures at each end and the difference in the size of the end pistons is such as to compensate for the weight of the reversing valve and rod so that these parts are always in balance.

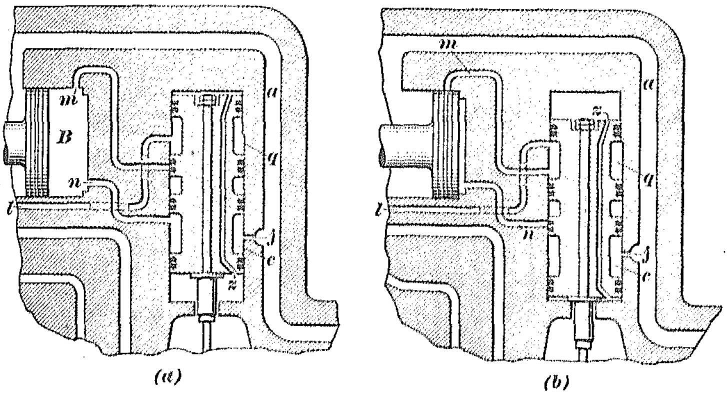


FIG. 38

The chamber q between the two upper pistons corresponds to cavity q, Fig. 29, of the slide-valve type and is always in communication with the exhaust port. The chamber c between the two lower pistons is at all times open to the steam inlet through

port *j*. Passage *n* conducts the steam from the reversing-valve chamber to chamber *B*, and *m* is an exhaust passage that communicates with passage *f* with the reversing valve in its down position. The reversing-valve cap serves as a bush for the upper piston and permits the removal of the reversing valve in the same manner as does the slide-valve type.

The new main valve, Fig. 37, is of one-piece construction and the small end piston has been made the same size as the intermediate pistons. The use of a bushed cover for the large piston end and a flat cover on the small piston end makes it possible to apply the main valve without danger of breaking the rings, since all rings can be observed. The reference letters shown have the same significance as those shown in Fig. 26.

RECONDITIONING THE COMPRESSOR

103. Cleaning the Compressor.—Compressors are thoroughly overhauled in the back shop and the following explains the order followed by some railroads in doing this work. When received in the shop the compressor is generally more or less greasy both on the outside and inside and it is cleaned by immersing the complete compressor in a lye vat, at the boiling point, and left there sometimes as long as a day. It is then removed and what dirt and scum remains is blown off with live steam, and washed off with water. Next the compressor is mounted on a work rack at one end of the repair bench, the rack being so arranged as to permit the compressor to be turned easily to any position desired. If, as is usually the case, the repair bench is equipped with an air line and the necessary connections for connecting the steam end of the compressor with it, the compressor is now operated by compressed air for a few minutes to blow out all of the lye water from its interior. At this stage an examination is made for such defects as cracked cylinders, cracked heads and brackets, and leaky joints between the cylinders and the centerpiece, indicated by a mixture of lye water and air seeping out of a crack. In other shops, the compressor is dismantled before cleaning; all the parts are then placed in a wire basket and placed in the cleaning solution. This

method has advantages over the one just described in that both the interior and exterior surfaces can be blown off with live steam, and particular attention given to the passages and ports.

104. Stripping.—The compressor can be stripped more conveniently by swinging it to a horizontal position on the work rack. The head is taken off the air cylinder so that the air piston can be removed. This is done by moving the air piston close to the open end, where the nut can be split open and knocked off, or the nut can be started with a short box wrench and a hammer. A few sharp blows will start the nut. Another method is to use clamps to hold the piston while the nut is being turned off. After the nuts are removed, the joint is broken by striking the end of the rod with a soft-faced hammer. The air piston may have two small holes tapped in it so that bolts can be turned in and the piston pulled out. The caps are next removed from the main valve chamber in the steam head and the main piston and valve removed. The gaskets if in good condition are saved. The reversing valve is also removed, the top head is taken off the steam cylinder, and the steam piston and rod are pulled out in the same manner as the air piston. The packing nuts, the old packing, and the glands can now be removed; next the caps, after previously being marked, are removed from the air-valve chambers, and the valves and the valve seats are examined.

It should be determined, before proceeding further, just what new material is required and an order should be placed for it. It will be apparent from what will follow later just what new parts will be required.

105. Cylinder Work.—The amount the cylinder is worn will be proportionate to the length of service. The bore should be the same diameter throughout to insure a proper fitting piston and air-tight rings. The wear can be determined by calipers and if either cylinder is found to be more than $\frac{1}{32}$ inch out of round, reboring and grinding will be necessary.

The cylinders are usually rebored on the boring mill or rebored and ground on a grinding machine. If the work is done by grinding, the whole compressor is mounted on the machine but, if

done on the boring mill, the cylinders will usually have to be removed from the centerpiece. On the cross-compound compressor, the reboring is done by a portable boring machine, if no grinder is available. Grinding is to be preferred, as the finish is much better and there is less liability of taper. The disadvantage in boring is the error introduced by the spring in the cutting tool or boring bar.

When reboring or regrinding the cylinders, the best practice, when the railroad company manufactures its own pistons and rings, is to remove only what is necessary to bring the cylinder back to its cylindrical form. However, if the pistons and rings are purchased from the manufacturer, the cylinder should be bored in steps of $\frac{1}{16}$ inch. For example, an $8\frac{1}{2}$-inch cylinder, after the grinding is finished, should be exactly $8\frac{9}{16}$ inches, but if this dimension will not clean the cylinder up, it should be ground to $8\frac{5}{8}$ inches. Rings can be procured from the manufacturer to fit the cylinder accurately when ground only as just stated. The high-pressure cylinders of the $8\frac{1}{2}$ cross-compound compressor can be bored $\frac{1}{4}$ inch larger than standard and the low-pressure cylinders to a diameter of $\frac{5}{16}$ inch larger than standard. This means that the manufacturer can supply five rings of different size for the high-pressure cylinders, and six rings of different size for the low-pressure cylinders. In addition to this, the rings may be obtained in several different widths to compensate for the wear of the grooves in the piston.

106. The wall of the cylinder is reduced in thickness every time that the cylinder is rebored, so there is a limit to which the reboring can be carried. It is poor practice to enlarge the bore of the cylinders more than $\frac{1}{4}$ inch because of the liability of the failure of the wall. When this limit has been reached, a new cylinder should be applied or the old one bushed, depending on the practice followed.

It is very important to maintain the by-pass grooves in the low-pressure steam cylinder at the proper depth according as the bore of the cylinder is enlarged by frequent reboring. The proper depth of these grooves is $\frac{3}{16}$ inch with a radius of $\frac{7}{16}$ inch, and the spacing is $1\frac{37}{64}$ inches, center to center. It is very impor-

tant that the end of each groove, which is 2 inches in length, is made square with the sides.

When the cylinders are again applied to the centerpiece, a new gasket should be used, but if the old one is in good condition and not broken anywhere, it can usually be used. All bolts and cap-screws that have been removed should be annealed before being reapplied. A gasket can be used over again in an emergency if heated in a fire and plunged in cold water. This anneals the copper and restores its flexibility. Sprinkling salt on the gasket while heating it will remove the scale and restore the color. Some roads make a practice of rebeading old gaskets, thereby making them nearly as good as when new. It is always advisable to use the best gaskets between the cylinder and the centerpiece, and if a poor gasket must be used in an emergency it should be used where it can be most easily replaced, namely, between the air cylinder and its head.

107. Piston Work.—It is seldom possible to use the old pistons for use in the rebored cylinders. Either a new piston that is oversize is taken from stock or a used piston from a larger cylinder is selected, care being taken that the diameter of the rod is within the proper limits. The piston is turned down to the proper size and the grooves of an old piston, if used, are cleaned out and the piston rod is trued up in a lathe or a grinding machine so that it will work smoothly in the packing; also, extreme care should be taken to see that the rod is not loose in the head. An air piston is also selected for the air cylinder, turned to the proper diameter, and properly fitted to the end of the rod. The reversing plate on the steam piston should be examined to see that it is tight. To obtain the best results, the piston should make a neat fit in the cylinder; if the piston will move down by its own weight the entire stroke, the fit is not too tight.

108. Manufacture of Rings.—Sometimes the piston rings are carried in stock in a semifinished condition instead of being carried in sizes to fit a certain diameter of cylinder. In order to put the required amount of spring in such a packing ring, it must originally have been turned out of material some-

what larger than the diameter of the cylinder that it is to fit, in which event the ring will bear in the cylinder only at the joint and at a point directly opposite it, hence it will not fit the bore snugly all the way around. To machine the rings to fit the cylinder they are first placed in a bushing about $\frac{1}{8}$ inch larger than the cylinder, their ends being cut diagonally and fitted to meet. A plate is inserted into each end of the bushing, through which is passed a mandrel with a shoulder on one end and a thread and a nut on the other; then, when the nut is tightened, the rings are bound together and prevented from springing out or expanding. The arrangement is next removed from the bushing and placed between centers on a lathe. As already explained, the exterior portions of the rings are not perfectly circular, but they are made so by taking a cut across their outer surfaces on the lathe. The diameter is reduced until the rings are just large enough to permit a final fitting, or to a size slightly larger than the cylinder. They will then not only have the same amount of spring that they had before, but in addition they will make contact all the way around.

109. Fitting of Rings.—The rings should always be tried in the grooves in the piston beforehand to see that they are not too loose, especially if a second-hand piston is being used, because a ring that fits too loosely in its slot will never be tight.

Rings that have been turned truly cylindrical as just outlined should be tried in the cylinder and the amount the ends overlap noted when at the point of smallest diameter, although with the grinding done accurately the diameter should be the same throughout. If they have been turned to the proper size, there will be a slight amount of lap, as in Fig. 39, and the ends of the ring should be reduced with a file until the

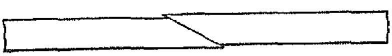


Fig. 39

lap can be just felt with the finger when the ring is reapplied to the cylinder. Considerable difference of opinion exists as to the advisability of fitting rings with a slight lap; but regardless of how well a ring is finished, there is certain to be a slight amount of wear during the first few hours of service. After the wear takes

place, the ring will expand slightly, and the lap will then be reduced or will disappear entirely.

Experience has shown that no necessity exists for a gap in the rings; on the contrary, a gap reduces the efficiency of the compressor. A gap would be necessary if the ring were subjected to more expansion than the cylinder, but as both are at approximately the same temperature, the expansion is about the same in each. At any rate, there is not enough difference to warrant the necessity for a gap to prevent breakage in cylinders that have been properly ground. If the cylinder is tapered, the ring must naturally be fitted to the smallest diameter; hence a gap will show up with the piston in the largest diameter of the cylinder.

110. Application of Rings.—The rings can be applied to the piston in two ways, either one of which is good. One method is to lay the ring flat on the piston and off center enough to permit one end to be gently sprung down into its groove. The remainder of the ring is then eased down over the edge of the piston a little at a time; after the edge is cleared all the way around, the ring will slip readily into the groove.

Another method is to enter the two ends of the ring into the groove at the same time with the ring at an angle of about 30 degrees to the piston. The ring is then worked over the edge of the piston from each end; as the ring is worked on, it opens out, finally permitting the part of the ring opposite the joint to clear the edge of the piston. The ring after application should be moved around in its slot to insure that it is free and not tight at any point. Also, it should be possible to press the ring into the groove beyond the outer circumference of the piston from every side. If this cannot be done, either the groove is not deep enough, or there is something in the bottom of it. The rings should also be tested for lateral play. Under no condition should the lateral play be greater than to permit free movement of the ring. For a ring that is properly ground and the slot in good condition, $\frac{3}{1000}$ inch lateral is sufficient; that is, the slot should be this amount wider than the ring.

A loose-fitting ring permits steam or air to work into the slot and under the ring and expand it, thereby increasing the friction

between the ring and the cylinder. This generates unnecessary heat, often causing an overheated air cylinder and destroying lubrication. The effect of poor-fitting rings on the temperature of the air cylinder is often overlooked.

111. Application of Pistons.—Before applying the steam piston, which is the first one put in, the condition of the stuffingboxes should be noted, particularly the thread. A damaged thread can be remedied by running a die over it, and damaged stuffingboxes or those that leak around the thread should be renewed. The two glands, the packing, and the nuts are then placed in position loosely, the cylinders are thoroughly cleaned, the ports are blown out, and the cylinder is lubricated. The steam piston and the rod are next entered in the cylinder, care being taken that the end of the rod does not tear the packing. The piston rings are then squeezed together and the piston guided into the counterbore. A solid blow with a block of wood on the piston will start it into the cylinder. The second ring is now entered into the counterbore and another blow will drive the entire piston in. The foregoing procedure shows the necessity of having the counterbore free from sharp corners. Owing to the lap on the rings, the steam piston will be so tight that it will have to be driven to the bottom of the cylinder.

The air piston is next entered into its cylinder in a similar manner and driven on to the rod far enough to start the first nut. A block is held against the end of the steam piston to keep it from moving out; or, if the compressor is being assembled on the floor, the block can be stood up on the floor and the steam piston placed on it. Then the nut is tightened and the piston driven, this being alternated until, as indicated by the blow becoming solid, the piston is up against its shoulder on the rod. There should be about $\frac{1}{16}$ inch of draw on the rod to insure tightness. Owing to the tendency of the pistons to turn while the nut is being tightened, the wrench used is a heavy one and is turned by striking it with a hammer rather than turning it by hand.

Should the rod happen to be crystalized, it may snap off during the application of the air piston, or during service, so that

it is good policy to anneal the rod at each shopping. Finally, a locknut and a split pin are applied.

112. Main Valve and Left Main-Valve Cylinder-Head Bushings.—The main-valve bushing of a $9\frac{1}{2}$-inch and an 11-inch compressor has a cylindrical portion for the large differential piston and a flat portion for the slide valve. The bushing is removed from the head by a press, and the portion in which the differential piston operates is calipered for wear. If found to be worn excessively or to such an extent that a new piston is too small, a new bushing should be used. If the old bushing can be used, the slide-valve seat must be reconditioned or trued up by filing or it is machine-finished in an attachment made especially for the purpose. The slide valve is refaced and afterwards ground in to its seat. This is done by fitting in the slot in the top of the valve a piece of wood of a length sufficient to extend out of each end of the bushing and moving the valve back and forth on its seat. The surfaces to be ground in are first coated with a grinding compound and oil, and are frequently inspected while they are being ground to make a good bearing. A finer grinding compound is then used to make a finer finish. The bushing is coated with oil and pressed back in, proper care being exercised to see that the ports in the bushing line up with the ports in the head. Some shops do not grind in the valve until the bushing has been pressed back into the head. This precaution is taken owing to the liability that the bushing will be distorted while being pressed in.

The large end of the main-valve piston of the $9\frac{1}{2}$-inch and 11-inch compressors operates within the main-valve bushing; the small end operates within the left main-valve cylinder head. This head should be calipered and rebored if worn excessively, and as it forms a continuation of the main-valve bushing the head must be set up in the lathe to insure that this alinement is maintained. The small port that leads from the inside of the head to the face should be thoroughly cleaned out, otherwise the compressor will not operate.

113. Renewing Rings on Main-Valve Piston. Two new rings are applied on each piston of the main valve.

Before application they are properly fitted into their cylinders; that is, the small rings are fitted into the left main-valve cylinder head and the larger rings into the cylindrical portion of the main-valve bushing. Each ring is filed to form a diagonal joint with no gap. The rings are tried in the grooves of the pistons to check the width of the slot. Rings of insufficient thickness should not be used. Rings with too much spring have a tendency to bind in the bushing and prevent the valve from moving quickly when reversing. In all cases, oversize rings must be kept for rebored bushings.

114. Reversing-Valve Bushing.—The reversing-valve bushing is pressed out at the same time as the main-valve bushing. As the reversing-valve seat is usually worn and contains carbon, some shops have a broaching tool that is passed through the bushing by a hydraulic press, and that cleans out the bushing and renews the seat. The seat is then touched up with a smooth file and the reversing valve is ground in to its seat in the same manner as the main valve. If the old reversing valve is used again, its base will have to be reconditioned before it is ground in to its seat. When valves are used the second time, the amount of slack between the valve and the rod should be checked, as well as the clearance between the top of the valve and the inside of the bushing. If either the slack or the clearance is too great, the old valve should be replaced. The same applies also to the main valve, as too much slack interferes with the proper operation of the pump and the valve may become unseated easily. The bushing can now be reapplied to the steam head, care being taken that the ports line up properly before being pressed in.

115. Reversing Rod.—In most cases the old reversing rod is worn too much at the shoulder where it engages the upper part of the reversing valve and at the button on the lower end, to continue it in service and it is replaced by a new one from stock. If worn to such an extent as to increase its length $\frac{1}{16}$ inch, it should be discarded. It is very important to see that the rod is straight.

116. Reconditioning Upper Air-Valve Seats.—The constant hammering of the air valves on their seats when the compressor is in operation usually increases the width of the valve seats in the manner shown in Fig. 40. The proper width of the seat is shown at *a*, while the constant hammering causes it to widen as shown at *b*. Such a seat is useless unless it can be brought back to its normal width, by facing off the top to a depth shown by the dotted line *c*. The tool used to reface an upper valve seat comprises a flat milling cutter with a long stem that extends up through a thrust bearing, which in turn is screwed into the opening normally filled by the valve cap. Turning down the thrust bearing forces the cutter against the top of the valve seat and when the cutter is revolved by its stem the seat is faced off. After the seat has been faced off to the required depth as shown by frequent inspection, the flat cutter is removed and a beveled cutter is inserted in its place and operated in the same manner until the proper width of seat is obtained. A good smooth finish is necessary.

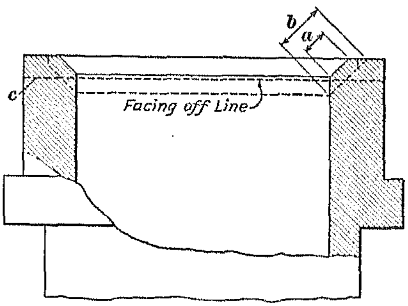


FIG. 40

117. Grinding in Upper Air Valves.—As the old valve is useless after the seat is reconditioned, a new valve is ground into its seat by using a grinding compound and continuing the grinding until a good bearing is made all the way around. The grinding compound is placed on the surface to be ground in, the valve is placed in position on its seat, and rotated by means of a brace with an end shaped to fit the slot in the top of the valve. If a very fine finish is desired, a finer grade of grinding compound is used.

118. Valve-Cage Work.—The valve cages in the bottom of the compressor are removed with a special box wrench. If the valve seat of the cage is reconditioned in a lathe, a new valve is ground into the cage by means of the lathe rather than by hand.

The shoulder of the cage, or the part that makes contact with the cylinder, is cleaned up in the lathe, as light a cut as possible being taken; also the part of the cylinder that the shoulder comes in contact with is cleaned up with a hand milling cutter similar to the one already described. The boss in the upper end of the valve-cage pocket, which acts as a stop for the valve, is smoothed over with a hammer. When cleaning up the shoulder of the cage, special precautions must be taken to set it up accurately in the lathe so that the cleaned-up surface will be true with respect to the thread; otherwise the shoulder will bear on one side only and leave the other side open. Care should also be taken to face off the cage seat square.

A new cage should be applied in cases where it is found that the cage does not make a good fit in its pocket; that is, the threaded part of the cage does not fit the thread in the pocket as tightly as it should. The old cage, if applied, will leak and possibly turn out.

119. Valve-Cap Work.—The upper inlet and discharge-valve caps are replaced if found to be battered or deformed or if the thread fits loosely. Any cap can be made tight by merely grinding it in and screwing it down firmly, but with a loose-fitting thread the cap will very shortly begin to turn out. Constant removal and application is the cause for worn threads.

The face of the shoulder on the cap, if marred or scored, is cleaned up in a lathe after being carefully set up. The boss on the inside of the cap is also faced off.

120. Seating In Caps and Cages.—In addition to having the thread air-tight, it is also important that the shoulders on the caps and cages should make a tight joint when screwed down. To insure that the shoulders seat all the way around, they should be ground in; this work is done by coating, with a grinding compound, the faces where the shoulders seat, and then lubricating the thread on the caps and cages to eliminate wear as much as possible. The cap or cage is first turned on tight, then backed off a quarter of a turn and turned in again, this process being repeated until inspection shows that the shoulder and the face of the casting is making a bearing all the way

around. Finally, the parts and their faces are washed off with gasoline.

121. Adjusting Lift of Air Valves.—The inlet and discharge valves of the 9½-inch, 11-inch, and the new pattern 8½-inch compressor have a lift of $\frac{3}{32}$ inch. A lift of less than this at the discharge valves will restrict the outflow of air, cause overheating, and slow up the compressor; a greater lift will cause the valves to hammer on their seats. A new valve must be applied when the lift reaches $\frac{5}{32}$ inch or $\frac{1}{16}$ inch more than specified. When the lift of the intake valve is less than standard, the inflow of air will be restricted, and the capacity of the compressor will be reduced; too great a lift will result in damage to the valve and its seat.

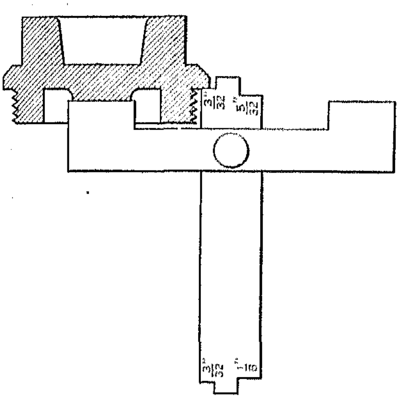


Fig. 41

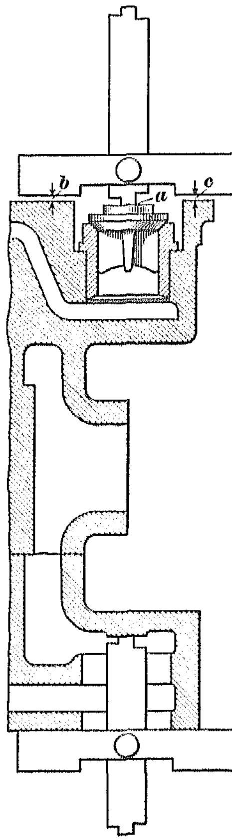


Fig. 42

The correct lift of the air valves is arrived at by facing off the proper amount from the boss on the top of the valve, because with new valves this boss or stop is always made thick enough to permit the proper lift to be obtained after the valve cages and valve seats have been reconditioned. The air-valve lift gauge

shown in Fig. 41 is used to determine the amount to be faced off the stops to obtain the proper lift of the valve. To ascertain the amount to be faced off the stop of the upper valve, the gauge is applied to the cap as shown, the thumb nut is slackened off, and the blade is adjusted until the proper step is brought into contact with the shoulder on the cap; the thumb nut is then tightened. The gauge is next applied to the face of the pocket with the valve in place. The condition that now exists is as shown in Fig. 42 and the amount shown at *b* or *c* when properly faced off the stop in a lathe will give the valve a lift of $\frac{3}{32}$ inch. That is, when this amount is faced off the valve, the gauge will make contact at *a*, *b*, and *c*.

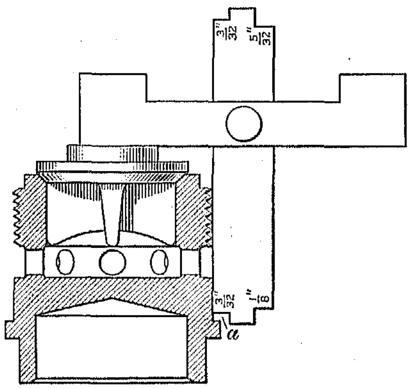


FIG. 43

The limit of wear with an old valve can be checked by adjusting the gauge to the cap as just explained, then applying the gauge to the pocket. The gauge will make contact at *b* and *c* but, if the opening at *a* is $\frac{1}{16}$ inch or more, a new valve is required.

122. To determine the amount to be machined off the lower inlet valve or discharge valve, the gauge is first applied and adjusted to the bottom of the pocket as shown in Fig. 42, and the thumbscrew tightened. As shown in Fig. 43, the gauge is next applied to the boss of the valve when in position in the cage. The amount to be faced off the valve will then be shown by the width of the gap at *a*. When the proper step is applied to the seat of the cage and a gap of $\frac{1}{16}$ inch or more exists between the valve stop and the gauge, the valve has too much lift and should be replaced.

123. Practice in Some Shops.—Some shops consider it more economical to renew valves, valve seats, and cages rather than to recondition the old ones. Where such practice exists,

air-valve work is comparatively simple and comprises the application of new parts and the grinding in of the valves.

Valve seats that are worn too wide are discarded. A seat is also discarded if it is found, when a new valve is applied, that there is too much side play. A new valve is applied if the stop or boss on the top is not high enough, thereby giving an improper lift. A valve cage is replaced for the same defects that would condemn a valve seat. About all of the work performed on the valve cap is to clean up the shoulder and the thread. The lugs on the under side of the valve caps should bottom on the valve seat.

124. Grooves in Bush 107.—The bush *107*, Fig. 26, is now supplied with four grooves $\frac{3}{32}$ inch wide and $\frac{1}{16}$ inch deep equally spaced and located as shown in the sectional view in Fig. 44. These grooves were cut in the bush to overcome the severe vibration of the compressor that sometimes occurred when it was operating slowly, as when the governor has about shut off the steam. Under low steam pressure the reversing valve

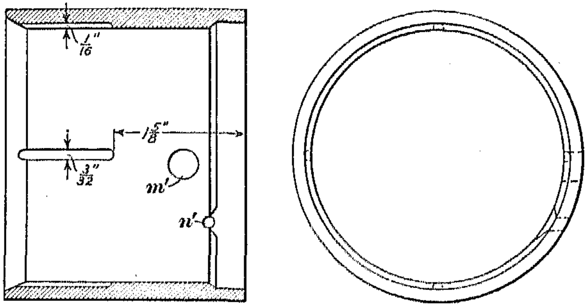


FIG. 44

may move down to such a position as to cause the valve to fail to develop and maintain full steam pressure on the outside face of the large piston of the piston valve. The effect of this is to cause the valve to move to the right or rebound as soon as the by-pass grooves in the cylinder for the small end of the piston valve open and partially balance this piston.

After the piston valve rebounds and cuts off the by-pass grooves, the small piston chamber is reduced to practically zero

through its exhaust port. Therefore the pressure on the outer face of the large piston, supplemented by the partially unbalanced condition of the small piston, causes the piston valve to move again toward the small end and the piston valve again rebounds when the by-pass grooves open. This action or partial reversal of the main valve occurs in such rapid succession as to produce severe compressor vibration.

125. The four by-pass grooves in the bush *107* cause the chamber on the outer face of the piston to charge before the by-pass grooves in the small piston cylinder nearly balance the pressure at this end, thus preventing the rebound of the piston valve with the resultant vibrating action. The grooves do not interfere with the normal operation of the compressor because, owing to the speed at which the piston valve then moves, there is little opportunity for the steam to pass through them.

Before the introduction of grooves in the bush *107*, chattering in some cases was traced to the improper location of port *o*, Fig. 30, which, through error, was sometimes so drilled in the small bush as to close before the by-pass grooves. Relocating this port so that both the port and the by-pass grooves closed simultaneously corrected the chattering action.

A-1 ENGINE EQUIPMENT

Serial 2511 Edition 1

WESTINGHOUSE AUTOMATIC AIR BRAKE

DESCRIPTION AND OPERATION

1. The general arrangement of the A-1 engine equipment, the FL tender equipment, and the brake equipment used on a freight car, is shown in Fig. 1. The letters FL used to designate the brake equipment on the tender refer to the type of triple valve and cylinder used. The construction and operation of the triple valve, brake valve, compressor governors, and of all the other important parts of the equipment, are here fully explained.

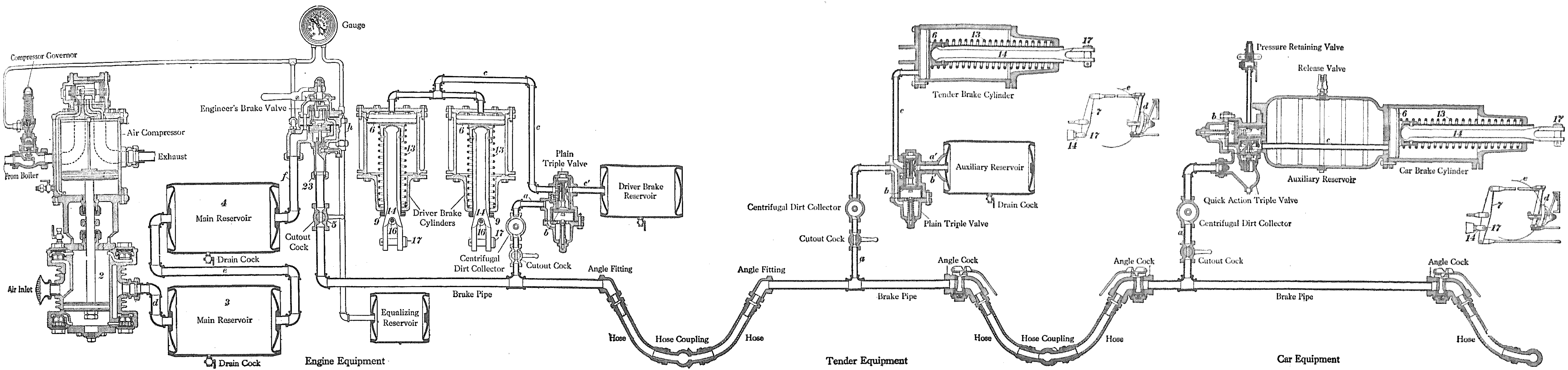
2. Names of Parts.—The important parts of the A-1 engine equipment as illustrated in Fig. 1 are: The steam-driven air compressor; the steam compressor governor; the main reservoir; the brake valve, including the feed-valve and equalizing reservoir; the duplex air gauge; the triple valve; the driver-brake reservoir, or auxiliary reservoir; the driver-brake cylinders; the brake pipe, including hose and coupling and branch pipe *a* to the triple valve; and foundation brake gear, part of which is shown, and which consists of levers, rods, brake beams, and brake shoes, the cylinder levers being attached to the brake-cylinder push rods *14* by pins *17*.

3. Arrangement of Parts.—The arrangement of the different parts of the air-brake equipment on the engine is as

follows: The steam compressor governor is placed in the steam pipe leading to the compressor. The pipe attached to the governor is connected at its other end to the air gauge and to a passage in the brake valve that is connected to the main reservoir by pipe *f*. The air end *2* of the compressor is connected by a pipe *d* to the main reservoir *3*. A radiating pipe *e* connects reservoir *3* with reservoir *4*, the purpose of this pipe or system of piping being to cool the air as much as possible in its passage from one main reservoir to the other. The engineer's brake valve is placed between the main reservoir and the brake pipe. A pipe *f* is used to connect main reservoir *4* to the brake valve, and the brake pipe is connected to the valve by a union nut *23*. The equalizing reservoir is connected to the brake valve by a pipe and T *h*. The black hand of the air gauge is also piped to T *h*. The handle *5* of the cut-out cock stands crosswise of the brake pipe when open.

The purpose of the cut-out cock, or double-heading cock, is to cut out the brake valves on all but the leading engine when more than one are coupled in the same train, and places the operation of the brakes under the control of the engineer on the leading engine, as the cock when closed prevents any operation of the brakes by the brake valve thus cut out. The double-heading cock is also closed when making certain tests for leakage. At all other times the cock must be open, in which position the handle *5* stands crosswise of the brake pipe.

The brake pipe is connected to the triple valve by a branch pipe *a*, which contains a cut-out cock and a centrifugal dirt collector. The cut-out cock stands crosswise of the branch pipe when open, similar to the double-heading cock, and should be closed when for any reason it is desired to render the brake on the engine inoperative. The dirt collector is used to collect dirt and dust that otherwise would be carried by the air into the triple valve. In addition to the branch pipe *a*, two other pipes are connected to the triple valve, pipe *c* leading to the driver-brake cylinders, and pipe *c′* leading to the driver brake reservoir. Pins *17* are used to connect the brake-cylinder push rods *14* to one end of the cylinder levers of the foundation brake gear.



BB514B 2511

Fig. 1

4. Arrangement on Tender.—The air-brake equipment on the tender consists of a plain triple valve, auxiliary reservoir, brake cylinder, brake pipe, and foundation brake gear, a portion of the latter being shown. The triple valve is connected to the brake pipe by a branch pipe *a*, which also contains a cut-out cock and a centrifugal dirt collector. Pipe *c* is used to connect the triple valve to the brake cylinder. The branch pipe *a* is supplied with a cut-out cock which when closed cuts out the brake on the tender, as brake-pipe air is then prevented from passing to the auxiliary reservoir. A triple-valve bracket *a′* and a nipple *b′* are used to support the triple valve on the auxiliary-reservoir head. The nipple *b′* consists of a short piece of pipe threaded on both ends and it runs through the hollow bracket *a′*. One end of the nipple is screwed into the auxiliary reservoir, and the other end into the threaded opening of the triple valve. Pin *17* is used to connect the crosshead of the push rod *14* to the cylinder lever *7* of the foundation brake gear on the tender. The connection between the brake pipe on the engine and tender is made by hose which can be readily connected or separated by a suitable hose coupling. The nipples on the ends of the hose are screwed into angle fittings on the brake pipe.

5. Arrangement on Car.—The air-brake equipment on the car consists of a brake pipe, quick-action triple valve, auxiliary reservoir, brake cylinder, foundation brake gear, a portion of which is shown, and a retaining valve. A branch pipe *a* is used to connect the triple valve with the brake pipe as in case of the engine and tender equipment.

The auxiliary reservoir and the brake cylinder are shown combined in the car equipment, although with some car equipments the auxiliary reservoir is detached from the brake cylinder because the construction of the car interferes with the installation of the combined equipment. The quick-action triple valve is bolted to the head of the auxiliary reservoir, and a part of the valve projects through an opening into it. The space therefore behind the triple piston *b*, as with the plain triple valve, connects directly with the auxiliary reser-

voir and may be considered a part of it. The auxiliary reservoir is made of cast iron, and the auxiliary tube *c* extending through it is used to connect the triple valve to the brake cylinder, as the front end comes opposite the brake-cylinder passage in the triple valve. The auxiliary tube has no connection to the auxiliary reservoir, but conveys auxiliary air after it passes through the triple valve to the brake cylinder when the brake is being applied, and back again through the triple valve to the atmosphere when the brake is being released.

The pressure-retaining-valve pipe is connected to the triple-valve exhaust port. The retaining valve has no effect upon the exhausting of brake-cylinder air until the handle shown is turned up, at which time it holds a predetermined pressure in the brake cylinder with the triple valve in release position.

6. The purpose of the release valve, or bleeder, shown on the auxiliary reservoir, is to discharge air from the reservoir and release the brake when the engine is detached, also when the engine is connected if the brake cannot be released in the usual way by increasing brake-pipe pressure. The brake cylinder contains a leather-packed piston *6* riveted to a hollow piston rod inside of which a push rod *14* operates. The outer end of the push rod is forked and is provided with a pin *17* to attach the rod to the cylinder lever *7* of the foundation brake gear. The push rod *14*, being separate from the piston, permits the hand brake to be operated without moving the piston. Connection is made between the brake pipe on the tender and on the car by hose screwed into angle cocks, the angle cocks being screwed onto the ends of the brake pipe. The angle cocks are used to open or close the brake pipe at the point at which they are located. The handles of the angle cocks stand the same way as the pipe when the cock is open and crosswise of the pipe when closed, or the opposite of the cut-out cocks.

7. The purpose of the foundation brake gear on the engine, tender, and car is to increase the force developed by the air pressure acting against the brake-cylinder pistons to the desired amount, and to transmit it equally to the wheels, thereby producing the friction or actual holding power of the brake.

AIR-BRAKE TERMS.

8. Definitions.—Following are definitions of the terms usually employed in connection with air-brake operation:

Increasing brake-pipe pressure means that more air is being supplied to the brake pipe from the main reservoir than is necessary to supply the leakage therefrom, which therefore raises the pressure.

Brake-pipe reduction means that air is being discharged from the brake pipe sufficiently fast to apply the brakes. This implies that the reduction is being made faster than the air is being supplied from the main reservoir through the engineer's brake valve or faster than it is being supplied from the auxiliary reservoirs by leaking back through the feed grooves.

Maintaining brake-pipe pressure means that sufficient air is being supplied to the brake pipe to prevent brake-pipe leakage from reducing the pressure, and yet without increase of the desired pressure.

The term **brake application** ordinarily means that the brake-pipe pressure has been sufficiently reduced by the brake valve or otherwise to cause the brakes to apply.

The term **service application** means that the brakes have been applied in the ordinary way or in service, as opposed to an *emergency* application.

A **full service application** is one in which the brake-pipe reduction or reductions has been such as to cause the brakes to be gradually but fully applied, which means that the auxiliary-reservoir and brake-cylinder pressures have become equal.

The term **emergency application** means that the brakes have been applied as quickly and as heavily as possible.

The term **over reduction** means a greater service brake-pipe reduction than is necessary to apply fully all connected brakes.

The term **overcharged brake pipe** means that the brake pipe has been charged above the adjustment of the feed-valve. A variation of the term is an *overcharged brake pipe near the engine,* which means that the brake pipe is overcharged at that point but not throughout the train.

The term **brake cycle** refers to the time elapsing between the beginning of the first service application, until the brakes are released and recharged ready for another application.

Piston travel is the distance the piston has moved outward in the brake cylinder when the brake is fully applied.

PLAIN TRIPLE VALVE

9. The plain triple valve was formerly used on both engines and cars, but is now only in use on engines and tenders having the A-1 equipment. As all the parts and functions of the plain triple valve are to be found in all modern brake equipments on both locomotives and cars, the later equipments having merely additional features, a thorough understanding of the plain triple valve will be of great assistance when the study of more modern air-brake devices is taken up. It is for this reason that the construction and operation of this triple valve is explained in detail.

10. Purpose and Description.—The purpose of the triple valve is to control the flow of compressed air from the brake pipe to the auxiliary reservoir, for charging the brake system; from the auxiliary reservoir to the brake cylinder, for applying the brakes; and from the brake cylinders to the atmosphere when releasing the brakes. The triple valve also holds the brakes applied by closing all communication between the brake pipe, auxiliary reservoir, brake cylinder, and atmosphere.

11. Four cross-sectional views of a plain triple valve as used on the tender with the A-1 equipment are shown in Fig. 2. Each view shows the triple valve in a different position; but view (*a*), which shows the triple valve in release position, will be used when describing its arrangement. The parts of the triple valve are: *1*, the triple body; *2*, the cylinder cap; *3*, the triple slide valve; *4*, the slide-valve spring; *5*, the triple piston; *6*, the triple piston packing ring; *7*, the graduating valve; *8*, the cap nut; *9*, the graduating stem; *10*, the graduating spring; *11*, the graduating-stem nut; *12*, the cylinder-cap gasket.

12. The branch pipe *a*, from the brake pipe, Fig. 1, connects to the triple valve at *W*; the pipe *c* leading from the brake cylinder connects at *X*, and the connection to the auxiliary reservoir is made at *Y*. The part of the triple-valve bush *s* on which the slide valve operates has two ports *h* and *f* cut through it, port *f* leading to the brake cylinder and port *h* to the exhaust port *k*. Air from the auxiliary reservoir passes through port *f* to the brake cylinder when the brake is being applied. A cavity *g* in the slide valve *3*, connects ports *f* and *h* when the triple is in release position as in Fig. 2 (*a*), thus opening the brake cylinder to the atmosphere through port *k*.

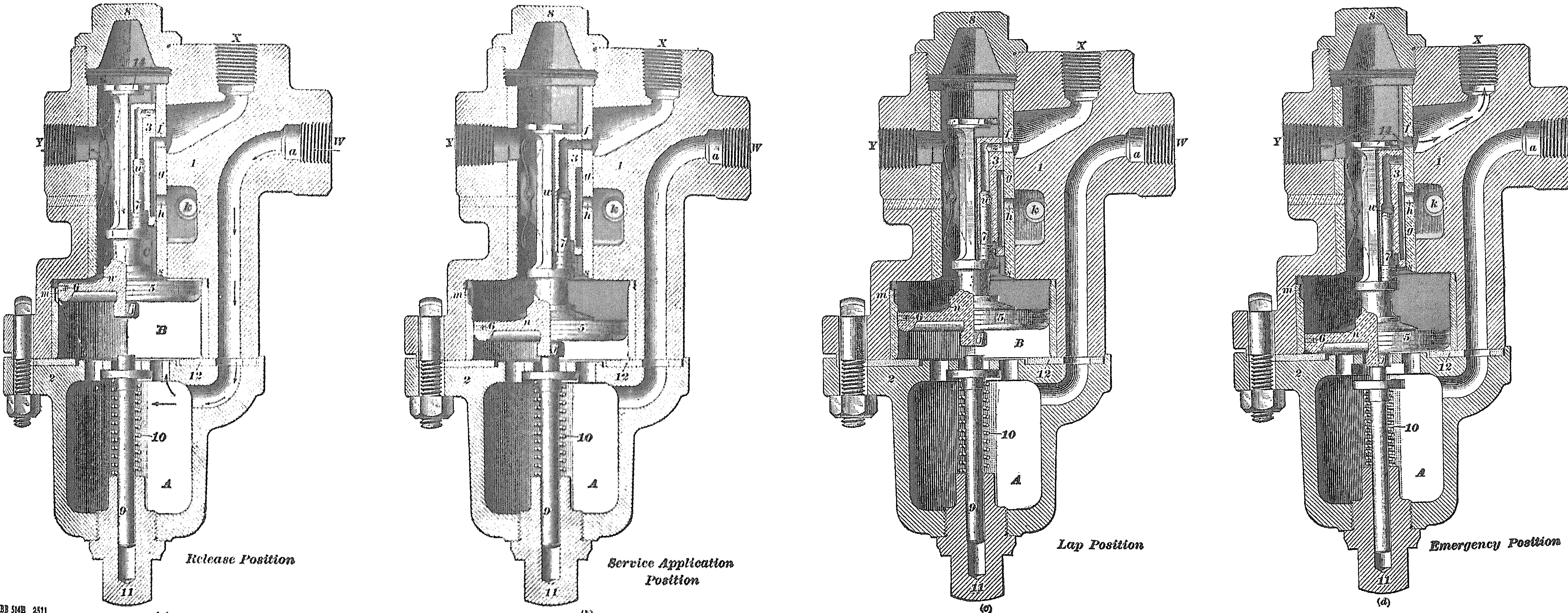
13. Air from the brake pipe enters at *W* and passes down passage *a* into chamber *A* in the cylinder cap *2*, and thence into chamber *B*, in which piston *5* operates. The piston *5* has a packing ring *6* the purpose of which is to prevent as near as possible the passage of air either way by the piston except when the piston is in its uppermost position as shown. In this position, a short feed groove *m* cut in the wall of the cylinder makes a very small opening around the piston, and groove *n* on the upper side of the piston prevents a joint being made where the lower end of the bush *s* comes in contact with the piston. The space *C* above the piston *5* is connected at all times to the auxiliary reservoir. Thus, when the equipment is charged, the lower side of the triple piston is exposed to air at brake-pipe pressure, *C* and the upper side of the piston has auxiliary-reservoir pressure acting against it, the two pressures being equal when the brakes are not being operated. Decreasing the brake-pipe pressure causes the triple piston to be moved down by the now greater auxiliary-reservoir pressure and, as will be explained hereafter, the brake will apply. Increasing the brake-pipe pressure above the auxiliary-reservoir pressure causes the piston to move upwards, and the brake will release. As the two pressures mentioned are constantly opposed to each other, the brakes will apply whether the brake-pipe pressure is intentionally reduced, as at the will of the engineer, or accidentally, as due to a burst hose, a hose parting, or any cause that produces a material decrease of pressure.

The air brake is then said to be automatic, this term applying to the application of the brakes only, as the brakes will apply whether the brake-pipe pressure is reduced intentionally or otherwise.

14. The graduating valve *7* is connected to the stem of the triple piston by a small pin which makes a loose fit where it passes through the graduating valve. The lower end of the graduating valve rests against the collar on the triple piston stem. (This construction is shown further on in Fig. 4, where *i* is the loose-fitting pin and *14'* the collar against which the graduating valve rests.) The graduating valve operates within an opening in the end of the slide valve *3*, and its upper end normally rests against the lower end of passage *z*.

15. The slide valve is located on the stem of the triple piston *5*, but is not fixed with respect to it, the arrangement being such as to permit of the triple piston's being moved either down or up a short distance without moving the slide valve. The collar *14* and the upper end of the graduating valve are the striking points that engage with and transmit movement to the slide valve when the triple piston is moving downwards and upwards. The triple piston can move downwards about $\frac{5}{32}$ inch before the collar *14* engages the slide valve, after which the piston can be moved upwards the same amount before the upper end of the graduating valve engages the lower end of port *z*.

The arrangement providing for an independent movement of the triple piston and graduating valve is found in all triple valves, the purpose of the arrangement being to permit of the brakes being graduated on with a slight difference of pressure. The friction of the triple piston packing ring being considerably less than the slide valve, the piston can move with a less difference of pressure than would be required to move the slide valve; therefore the triple piston can move, and thus move the graduating valve from lap to service position and back to lap, thereby graduating the application of the brake, as explained later under Service Application, with much less difference of pressure than if the piston had to move the slide valve.



Release Position

(a)

Service Application Position

(b)

Lap Position

(c)

Emergency Position

(d)

BB 514B 2511

Fig. 2

The graduating stem *9* is held in position in the cylinder cap *2* by the graduating spring *10* and the cap nut *11*. The purpose of the graduating stem and spring is to prevent the triple piston from moving past service position during a service application on a short train.

16. Slide Valve.—Five views of the slide valve are shown in Fig. 3. View (*a*) is a vertical section, view (*b*) shows the face of the valve, view (*c*) is a view taken on the

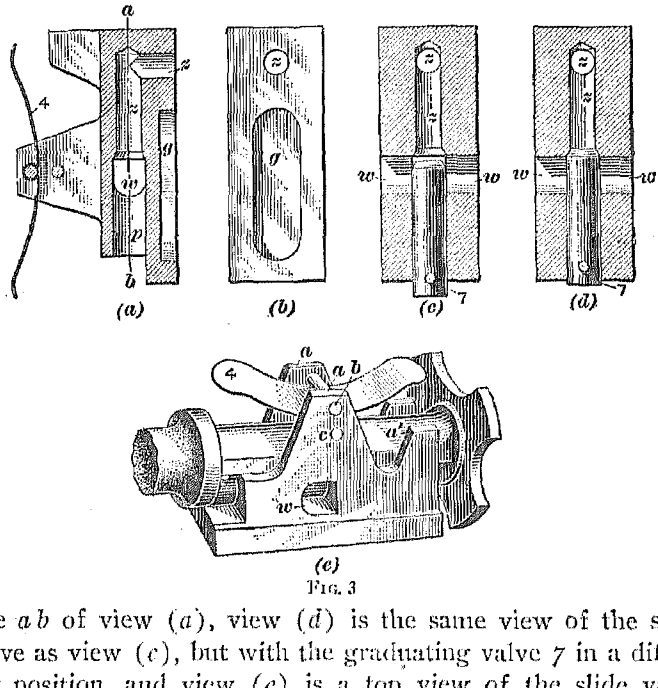


FIG. 3

line *a b* of view (*a*), view (*d*) is the same view of the slide valve as view (*c*), but with the graduating valve *7* in a different position, and view (*e*) is a top view of the slide valve attached to the piston stem.

The graduating valve operates within the opening *p*, view (*a*), the upper end of the valve seating against the lower end of port *z*. Port *z* leads to the face of the slide valve and connects at its lower end to port *w*, this latter port being drilled completely through the slide valve at right angles to port *z*, as shown in view (*c*). View (*b*) shows the exhaust cavity *g* in the face of the slide valve, and also the upper end of port *z*.

In view (c) the graduating valve is shown in its open position, and in view (d) the valve is shown in its closed position.

View (e) shows how the slide valve is connected to the triple piston stem. The stem operates loosely between the two sets of wings $a\ a'$ and a pin c that extends above the stem through the two wings a. Pin b passes through the spring 4 and serves to connect the spring to the slide valve. Spring 4 holds the valve on its seat in the absence of air pressure.

17. The slide valve, in addition to making a joint between the auxiliary reservoir and the atmosphere at all times, opens communication from the auxiliary reservoir to the brake cylinder when the brake is being applied, and from the brake cylinder to the atmosphere when the brake is being released.

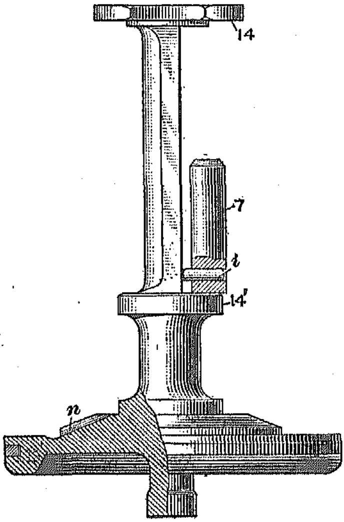


FIG. 4

18. Triple Piston and the Graduating Valve. Fig. 4 shows the triple piston and the graduating valve with the slide valve removed. The graduating valve 7 is connected to the stem of the piston by the graduating pin i, and moves with it.

The graduating pin fits solid in the piston stem, but is a loose fit where it passes through the hole in the graduating valve, this arrangement permitting the graduating valve to seat accurately.

19. The purpose of the triple piston is to move the slide valve and graduating valve, and to open and close the feed groove m in the triple piston bush. The small feed groove on the back of the piston is shown at n.

20. The purpose of the graduating valve is to secure a gradual and graduated application of the brake, by opening and closing the lower end of port z in the slide valve.

The upper end of the graduating valve is tapered where it seats against the lower end of port *z*, this construction permitting the valve to open the port gradually.

OPERATION OF TRIPLE VALVE

21. The text pertaining to the operation of the plain triple valve should be studied in connection with the illustrations shown in Fig. 2.

22. Charging Position.—In charging position, the triple valve controls the flow of compressed air from the brake pipe to the auxiliary reservoir, the passage of air through the brake system at this time being as follows: Air from the main reservoir, Fig. 1, flows through the engineer's brake valve into the brake pipe, thence through the branch pipe *a*, and enters the triple valve at *W*, Fig. 2 (*a*). When the triple is cut in, the air can flow in at *W*, and on through passage *a*, into chamber *A*, whence it passes into chamber *B*. If piston 5 were down, the air entering chamber *B* would force it up into release position, as in view (*a*). This movement of the piston opens the feed groove *m*, and air therefore feeds from chamber *B* past piston 5, through the grooves *m* and *n* into the slide-valve chamber *C*, which communicates through *Y* with the auxiliary reservoir. The air continues to feed past piston 5 as long as brake-pipe pressure in chamber *B* is greater than the auxiliary pressure in chamber *C*. The usual brake-pipe pressure is 70 pounds, and, when the auxiliary pressure reaches this amount, the pressure in chambers *B* and *C* is equal, and the auxiliary reservoir is said to be fully charged. The lower side of piston 5 is generally referred to as the *brake-pipe side*, and the upper as the *auxiliary side*, or the *slide-valve side*.

A modern triple valve should charge an auxiliary from zero up to 70 pounds in about 70 seconds, with a constant brake-pipe pressure of 70 pounds. With the triple in release position and the auxiliary charged, there will be 70 pounds pressure in the brake pipe, 70 pounds in the auxiliary, and atmospheric pressure in the brake cylinder, since the cavity *g* in the slide

valve connects the brake cylinder with the atmosphere, the communication being through port *f*, cavity *g* and port *h* in the slide-valve seat, and port *k*.

23. Service-Application Position.—The purpose of service-application position is to admit air from the auxiliary reservoir to the brake cylinder gradually, and only in such quantities at a time as the stop requires, the term *graduated* being applied to this latter operation. A graduated application of the brakes is obtained by the operation of the slide valve and the graduating valve, which derive their movement from the triple piston. The triple valve is made to apply the brake by reducing the brake-pipe pressure below that in the auxiliary reservoir sufficiently to overcome the friction of the moving parts. Placing the handle of the engineer's brake valve in service position gradually reduces the pressure in the brake pipe, and destroys the balance of pressure existing on each side of the triple piston in full-release position. If the pressure in the brake pipe has been reduced 5 pounds, the brake valve being then lapped, only 65 pounds will remain in chamber *B* on the brake-pipe side of the triple piston *5*. The greater pressure in the auxiliary reservoir forces the piston *5* down, thereby closing the feed groove *m* and breaking the connection between the brake pipe and the auxiliary reservoir, and unseating the graduating valve *7*, which opens the lower end of port *z*. Auxiliary-reservoir air, which is always present in port *w*, now passes the end of the graduating valve to the upper end of port *z*, but the air cannot pass out of the port *z* until the slide valve is moved to service position. The collar *14* on the upper end of the piston stem next engages the slide valve and begins to move it down, thereby breaking the connection between the brake cylinder and the atmosphere, which formerly existed through exhaust cavity *g* and ports *f* and *h*.

The piston continues to move the slide valve downwards until port *z* registers with port *f*, after which any further movement is prevented by knob *j* striking the graduating stem *9*. The triple valve is now in service-application position, as in view (*b*), and air from the auxiliary reservoir passes through

the ports *w* and *z* in the slide valve, thence through port *f*, and out at *X* into the brake cylinder, where the pressure will force out the brake-cylinder piston and apply the brake.

24. The air flowing from the auxiliary reservoir to the brake cylinder causes the pressure to reduce in the former and increase in the latter. The pressure continues to reduce in the auxiliary reservoir and chamber *C* until it becomes enough less than the pressure held in the brake pipe or chamber *B*, which is 65 pounds, for the higher brake-pipe pressure to overcome the slight resistance offered by the packing ring; the triple piston and graduating valve then move up until the graduating valve seats on the lower end of port *z*. The slide valve then prevents any further movement, because the difference between the pressure in the brake pipe and the auxiliary reservoir is not sufficient to overcome the friction of the slide valve. When the graduating valve *7* seats, it closes the communication between port *w* and port *z* and prevents any further passage of air from the auxiliary reservoir to the brake cylinder. This position of the triple piston and graduating valve is known as *lap position;* the slide valve, however, is in service-application position.

In lap position, the brake is held applied, on account of an approximate equality of pressure in the auxiliary reservoir and brake pipe. The slide valve prevents the further movement of the triple piston from lap toward release position, as the difference between the brake-pipe and auxiliary-reservoir pressures necessary to overcome the friction of the triple piston packing ring is not great enough to overcome the friction between the slide valve and its seat.

25. Lap Position.—The term **lap** as applied to the position of the triple valve shown in view (*c*) means that all ports are closed; that is, there is no communication between the brake pipe and the auxiliary reservoir, between the auxiliary reservoir and the brake cylinder, or between the brake cylinder and the atmosphere. With the triple valve in lap position, the brake-pipe and the auxiliary-reservoir pressures will remain approximately balanced and the brake-cylinder pressure will

be held constant until the brake-pipe pressure is further reduced to apply the brake harder, or is increased to release the brake.

If another service application is made, and the brake-pipe pressure is reduced 5 pounds, the approximate balance of pressure existing on either side of the triple piston in lap position will be destroyed, and the greater pressure in the auxiliary reservoir will cause the piston and attached graduating valve again to move to service-application position. The slide valve, however, being already in service position, does not move; consequently, as soon as the graduating valve is moved to open port *z*, air from the auxiliary reservoir flows to the brake cylinder, and increases the pressure therein and also the pressure of the brake shoes against the wheels. The piston and graduating valve will again assume lap position when the auxiliary-reservoir pressure falls slightly below the pressure now retained in the brake pipe. The movement of the graduating valve in opening and closing the service port *z* in the slide valve, graduates the application of the brake, or causes the brake-cylinder pressure to be increased a certain amount at a time, hence the term *graduating* as applied to this valve.

The continued movement of the triple piston and graduating valve from lap to service position and back to lap, causes the pressure in the auxiliary reservoir to fall and the pressure in the brake cylinder to rise, until the two pressures finally become equal, at which time the brake is said to be *fully applied.* After equalization occurs, the lapping movement of the triple piston and graduating valve stops, and the graduating valve keeps port *z* open, as the effect necessary to obtain this movement, namely a lower pressure in the auxiliary than in the brake pipe, due to the expansion of the auxiliary-reservoir air into the brake cylinder, can no longer be produced.

26. When the auxiliary-reservoir and the brake-cylinder pressures equalize, the brake is applied with its maximum pressure and nothing can be gained by further reducing the pressure in the brake pipe. Reducing the brake-pipe pressure after the brake has been fully applied constitutes an over reduction and wastes the brake-pipe air, which must be restored

before the triple piston and its attached valves can be moved to release position. However, if the brake-pipe pressure is further reduced, the triple piston will move the full length of its cylinder, and compress the graduating spring. The auxiliary reservoir will then be connected to the brake cylinder over the top of the slide valve, as in view (*d*).

A 20-pound brake application from a brake-pipe pressure of 70 pounds causes the auxiliary reservoir and brake cylinder to equalize at 50 pounds, and thus apply the brake in full when the piston travel is 8 inches.

27. Brake-Cylinder Pressure Developed.—The reason why a 20-pound brake application develops a brake-cylinder pressure of 50 pounds, can be more easily understood by considering Fig. 5 (*a*). Assume that the volumes of chambers *a* and *b* are equal, that chamber *a* is charged to a pressure of 70 pounds and that chamber *b* contains atmospheric pressure. Opening cock *c* and allowing the air in chamber *a* to pass to chamber *b* is equivalent to doubling the volume of chamber *a*, and according to the law governing the expansion of air, doubling the volume reduces the pressure by one-half. Therefore if cock *c* is left open, the pressure in chambers *a* and *b* equalizes at 35 pounds.

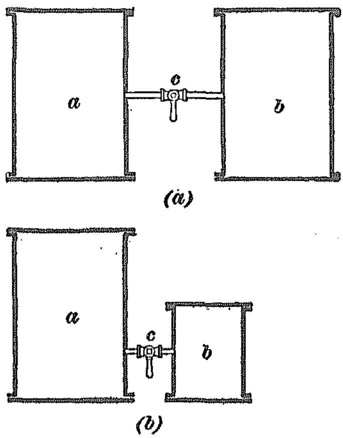


FIG. 5

With the conditions shown in Fig. 5 (*b*), assume that chamber *a* is a little more than $3\frac{1}{2}$ times the size of chamber *b*. Then, when cock *c* is opened, the pressure in both chambers will equalize at about 50 pounds instead of 35 pounds as before, since the amount by which chamber *b* has been enlarged is less than in the previous case.

28. The volume of the auxiliary reservoir supplied with each brake cylinder is about $3\frac{1}{2}$ times the size of the brake

cylinder with an 8-inch piston travel, so that when the auxiliary reservoir is charged to a pressure of 70 pounds per square inch and is then connected to the brake cylinder, the pressure in the auxiliary reservoir in expanding to the brake cylinder reduces from 70 pounds to 50 pounds, or 20 pounds, before the pressure in both becomes equal. Therefore a 20-pound brake application, as it reduces the auxiliary pressure 20 pounds, applies the brake in full under the conditions mentioned.

29. As a brake-pipe reduction of 20 pounds gives a brake-cylinder pressure of 50 pounds, it is apparent that each pound the brake-pipe pressure, and therefore the auxiliary-reservoir pressure, is reduced, develops an approximate pressure of $2\frac{1}{2}$ pounds in the brake cylinder. However, when air is first admitted to the brake cylinder it must first force out the piston and fill the piston displacement, and the pressure developed in the brake cylinder so long as the piston can move will only be sufficient to overcome the tension of the release spring in the brake cylinder and the friction of the rods and levers. Therefore a brake-cylinder pressure of $2\frac{1}{2}$ pounds for every pound of brake-pipe reduction is not developed when the brake is first applied.

After the cylinder volume becomes constant by the pistons bringing the brake shoes up against the wheels, the brake-cylinder pressure will begin to increase in the ratio of $2\frac{1}{2}$ pounds for each pound the brake-pipe pressure is reduced, up to equalization. Therefore the brake-cylinder pressure developed following service brake applications can be found quite closely by multiplying the brake-pipe reduction by $2\frac{1}{2}$. Thus when the brake-pipe pressure is reduced 10 pounds, the resulting brake-cylinder pressure will be $10 \times 2\frac{1}{2}$, or 25, pounds. If the pressure carried is higher than 70 pounds, the pressure of equalization will be more than 50 pounds, and if a lower pressure is carried, the brake-cylinder pressure developed will be less than 50 pounds. If the piston travel is less than 8 inches, the equalizing pressure will be higher and can be obtained with less than a 20-pound brake application; if more than 8 inches, the brake-cylinder pressure obtained will be less, and the brake

application must be more than 20 pounds to produce equalization.

30. Release and Charging Position.—When the brake-pipe pressure is increased above that in the auxiliary reservoir by allowing the higher pressure in the main reservoir to pass to the brake pipe, the triple valve operates so as (*a*) to connect the brake cylinder to the atmosphere through the release cavity in the slide valve, thereby releasing the brakes, and (*b*) to connect the brake pipe to the auxiliary reservoir through the feed groove and thereby permit the auxiliary reservoir to be recharged. When the triple piston moves the slide valve upwards to release position, view (*a*), Fig. 2, cavity *g* connects ports *f* and *h* and permits the air in the brake cylinder to escape to the atmosphere through port *k*. The feed groove *m* is then opened and brake-pipe air feeds into and charges the auxiliary reservoir to standard brake-pipe pressure. The triple valve at this time is said to be in *release and charging position,* as the brake is releasing and the auxiliary reservoir is charging at the same time.

31. Emergency-Application Position.—When a sudden and heavy reduction of brake-pipe pressure has been made in chamber *B*, the triple valve is moved to emergency position. This reduction may be produced by the brake valve, tail hose, conductor's valve, or a break-in-two, and causes the triple valve to move to emergency position because the pressure in the auxiliary reservoir cannot escape through the service ports to the brake cylinder as fast as the brake-pipe pressure is being reduced. The greater pressure in the auxiliary reservoir then forces the triple piston to the limit of its travel. The piston compresses the graduating spring *10* as shown in view (*d*) and seats on leather gasket *12*. In this position, a direct connection is established between the auxiliary reservoir and the brake cylinder across the upper end of the slide valve *3*. Auxiliary-reservoir air passes direct through port *f* and out into the brake cylinder at *X*, without having first to pass through the service ports of the slide valve. As only the large port *f* is used in emergency position, the pressure in the auxiliary

reservoir and the brake cylinders equalizes more quickly than with the smaller ports used in service position. With a plain triple, the brake sets more quickly in emergency than in service, but not with greater force, as the available pressure used to apply the brake is stored in the auxiliary reservoir. To get the full emergency action of the brakes with plain triple valves it is necessary to make an emergency application of about 20 pounds. The graphic illustration in Fig. 6 will be of assistance in remembering the arrangement and operation of the plain triple valve.

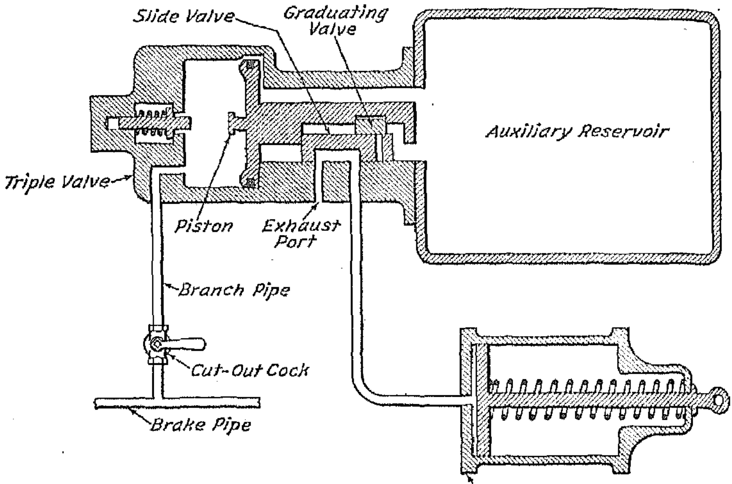


Fig. 6

G-6 AUTOMATIC BRAKE VALVE

32. Purpose of Brake Valve.—The purpose of the automatic brake valve, also known as the engineer's brake valve, is (*a*) to admit air from the main reservoir to the brake pipe when the brakes are being released, or the brake pipe charged; (*b*) to maintain a predetermined pressure in the brake pipe when the brakes are not being operated, by admitting main-reservoir air to the brake pipe through the feed-valve; (*c*) to allow the air to escape from the brake pipe when the brakes are being applied; and (*d*) to prevent the passage of air to or from the brake pipe when the brakes are being held applied.

In order to make the connections necessary to produce the above four effects, the G-6 valve has five positions, the extra position being necessary because the brake-pipe air is exhausted in two different ways. The brake-valve positions beginning at the extreme left are full release, running, lap, service, and

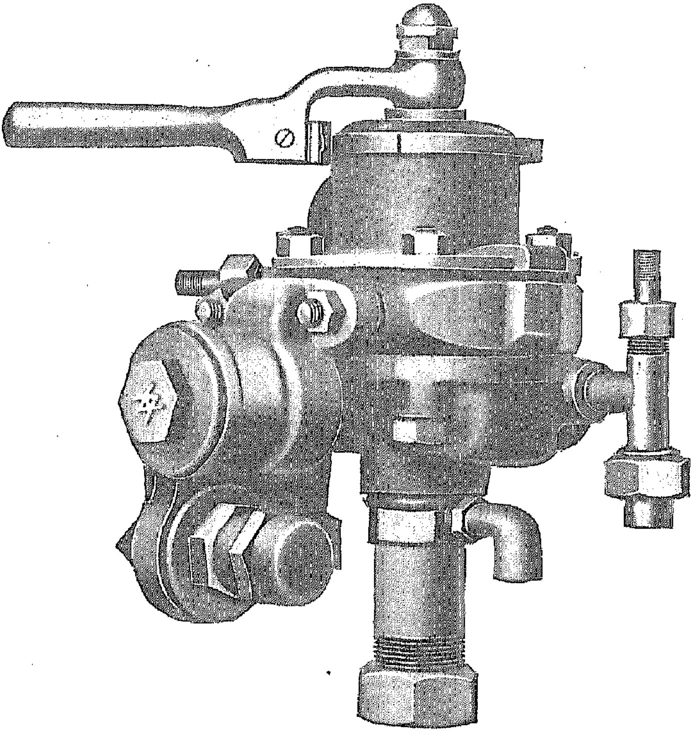


FIG. 7

emergency; and as each position performs separate and distinct duties the brake valve may be considered as five valves combined in one.

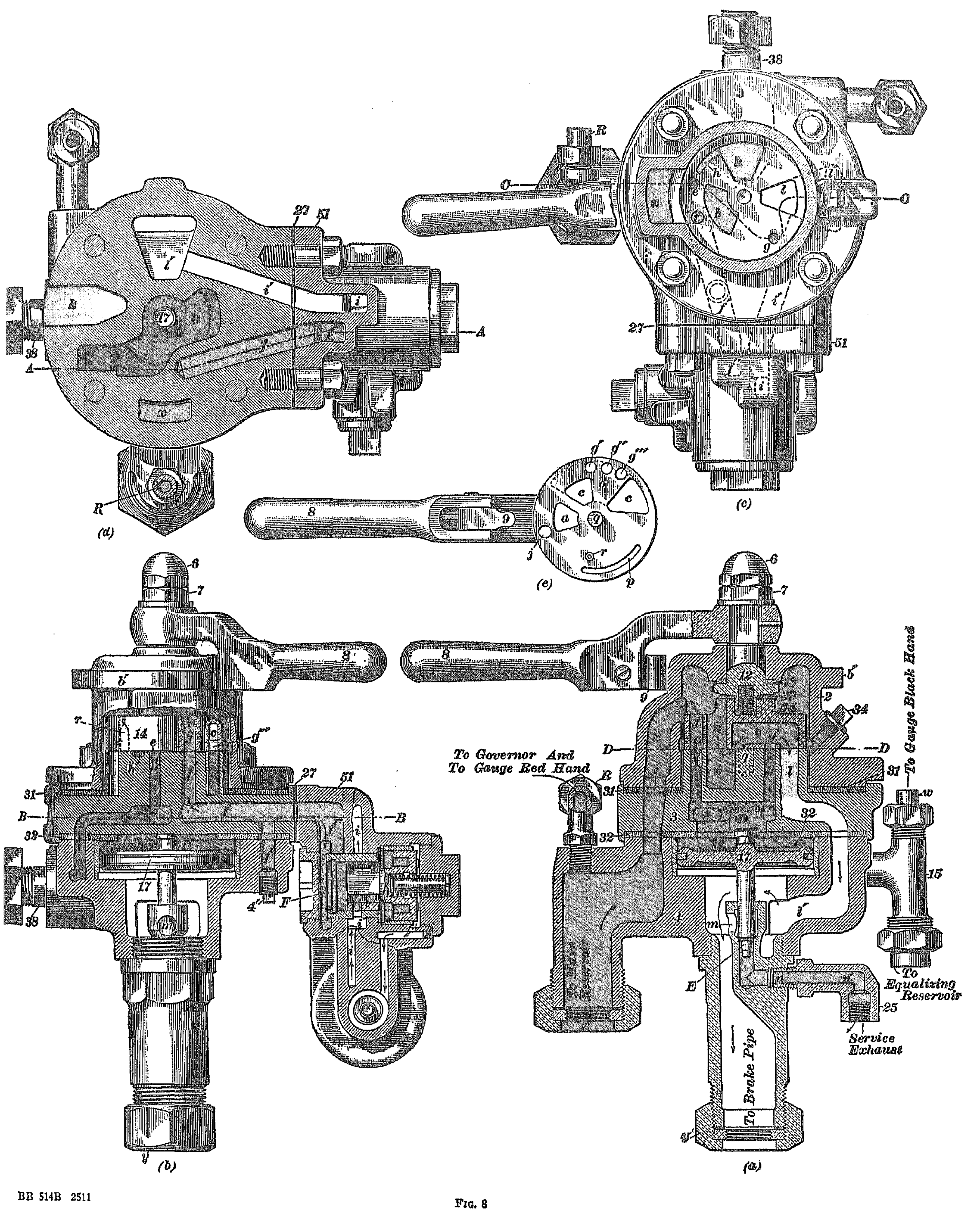
33. Description.—Fig. 7 is an exterior view of the G-6 brake valve and Fig. 8 shows four sectional views of this brake valve, and a face view of the rotary valve. View (*a*) is a side elevation, the valve being sectioned vertically on the line *C C*, view (*c*), this line running through ports *e*, *g*, and *l*. The

brake valve is shown in full release position in view (*a*). View (*b*) is a vertical section of the lower part of the brake valve taken on the line *A A*, view (*d*). The upper part or valve cap is shown broken away exposing a portion of the rotary valve *14*. The brake valve is shown in running position in view (*b*). View (*c*) is a plan view of the rotary-valve seat and shows the various ports therein, the brake valve being sectioned on line *D D*, view (*a*). View (*d*) is a section of the brake valve taken on the line *B B*, view (*b*), and (*e*) is a face view of the rotary valve, the brake-valve handle *8* also being shown.

34. The names of the parts of the G-6 brake valve, view (*a*), Fig. 8, are as follows: *2*, body; *3*, rotary-valve seat; *4*, bottom case; *6*, handle locknut; *7*, handle nut; *8*, handle; *9*, latch; *12*, rotary-valve key; *13*, key washer; *14*, rotary valve; *17*, equalizing piston; *25*, service-exhaust fitting; *31*, upper gasket; *32*, lower gasket; *38*, view (*b*), holding stud.

35. The automatic brake valve, to which the main reservoir and brake pipe are connected, consists essentially of an equalizing piston *17*, view (*a*), a rotary-valve seat, view (*c*), a circular rotary valve, view (*e*), which operates on the rotary-valve seat, all these parts being suitably enclosed. The ports in the rotary valve and the seat are so arranged that when the rotary valve is rotated by the handle *8* to the different positions, the ports will register so as to permit air to pass and operate the brakes in the manner desired for each position.

36. As shown in view (*a*), Fig. 8, the main-reservoir connection to the brake valve is made at *x*, and main-reservoir air can pass through passage *x* to the top of the rotary valve *14*. The pipe leading to the compressor governor and the red hand of air gauge is connected at *R*. When a duplex governor is used, the low-pressure head is connected by a pipe to port *f'*, view (*b*). A plug *4'* is used to close port *f'* when a single governor is used. The brake pipe connects to the brake valve at *y*, which brings brake-pipe pressure under the equalizing piston *17* and through passage *l'* to the lower face of the rotary valve *14*. The equalizing reservoir is connected to a T *15* which



BB 514B 2511

FIG. 8

is screwed into a passage in the brake valve that leads into chamber *D* above the equalizing piston *17* through port *s*. Therefore brake-pipe pressure is always below piston *17* and equalizing-reservoir pressure above it when the brake system is charged. The black hand of the air gauge is connected to the upper end of the T connection at *w*, and therefore this hand indicates the pressure in the equalizing reservoir, which is the same as the pressure in the brake pipe in full release and running positions, as these parts are then connected. In lap, service, and emergency positions, direct communication between the brake pipe and the equalizing reservoir is closed, the black hand then indicating approximate brake-pipe pressure. The difference between the two pressures in the three last named positions will be about 2 or 3 pounds, depending on the fit of the equalizing-piston packing ring *19*.

37. The brake valve, view (*a*), Fig. 8, consists of three portions: the lower portion *4*, extending down to union nuts *x* and *y* and containing the equalizing piston *17*; middle portion *3*, containing various ports and passages and terminating in the rotary-valve seat; and upper portion, or valve body, *2*, which is placed over the portion *3*. The three portions of the brake valve are held together by four bolts and nuts, view (*c*). A leather gasket *32* is placed between the lower portion *4* and middle portion *3* and prevents leakage of air from the main-reservoir to chamber *D*, between the brake pipe and chamber *D*, or to the atmosphere. This gasket, in connection with flange *18* on the equalizing piston *17*, also insures an air-tight joint between the brake pipe and chamber *D*, when the equalizing piston is raised to its highest position during service brake applications. A rubber gasket *31* placed between the upper and the middle portions of the brake valve, prevents leakage of main-reservoir air to the atmosphere. The upper portion *2*, views (*a*) and (*b*), has a projecting flange *b′* containing stops. The different positions of the brake valve are indicated by the position of the brake-valve handle *8* as its latch *9* engages these stops. A spring in the brake-valve handle holds the latch against the flange

38. The brake-valve handle *8*, Fig. 8 (*a*), is connected to the rotary-valve key *12*, by a handle nut *7* and a handle lock-nut *6*. A key washer *13* prevents any leakage of air past the rotary-valve key *12* when air pressure under it forces it up against the gasket. The lower portion of the rotary-valve key *12* is wedge-shaped and fits into a slot in the top of the rotary valve *14*, as shown; therefore any movement of the brake-valve handle is communicated to the rotary valve by means of the rotary-valve key. A spring *33* is inserted in a hole in the rotary-valve key and exerts a downward pressure on the rotary valve to hold it to its seat in the absence of air pressure. The rotary valve *14* has a guide pin *q* in its center, shown in view (*e*) and by dotted lines in view (*a*), that fits into a hole in the center of the rotary-valve seat, view (*c*). The pin *q* acts as a guide about which valve *14* rotates.

The holding nut and stud *38*, view (*b*), are used to attach the brake valve to its bracket. The oil plug *34*, by means of which the rotary valve can be lubricated, is shown in view (*a*).

39. The stem *E* of the equalizing piston *17*, view (*a*), Fig. 8, known as the equalizing discharge valve, normally seats in the end of passage *n* and controls the discharge of brake-pipe air in service brake applications by opening and closing passage *n n′* in the service-exhaust fitting *25*.

The opening through the exhaust fitting *25* is one-quarter inch in diameter, and the fitting is shaped as shown, to prevent a too rapid discharge of brake-pipe air, which would tend to cause the brakes to apply in emergency when making service applications, especially with short trains. The correct size and shape of passage *n n′* also prevents quick action in the event of the equalizing piston sticking during the beginning of the reduction, and then rising more rapidly than it should.

The absence of the exhaust fitting, with the equalizing piston operating properly, increases the rate of discharge of brake-pipe air and causes a more rapid application of the brakes, the result being more severe slack action and damage to draft gear. If a smaller fitting is used, as is sometimes done, the rate of discharge will be decreased, with the liability of some of the

brakes near the rear of long trains not applying. The opening through the service-exhaust fitting is smaller with the H-6 brake valve which is used with the ET equipment than with the G-6, because there is one less angle in the passage of the former valve.

40. The equalizing discharge valve is actuated by the equalizing piston *17*, and these parts operate in service position only. When the piston is moved upwards, brake-pipe air beneath it passes through port *m* to passage *n*, and when stem *E* returns to its seat, as shown, the further escape of brake-pipe air is prevented. The reason for the equalizing piston moving is the same as that already given for the movement of the triple piston, and is therefore due to unbalancing the pressure on either side of it. When the pressure in chamber *D* and the equalizing reservoir becomes less than that in the brake pipe, piston *17* moves up, and when the pressure becomes less in the brake pipe than in chamber *D*, the piston moves down.

The difference in area between the upper and the lower faces of piston *17* due to the stem, makes the total pressure on top of it somewhat greater than that below, thus assisting in holding the equalizing discharge valve to its seat when the brake valve is not being operated. The knob on the top of the piston permits the piston to be readily grasped to lift it out of the brake valve.

41. Ports in Rotary-Valve Seat.—The rotary-valve seat, Fig. 8 (*c*), contains ports *e*, *g*, *f*, *l*, and *k*. Port *e*, as shown in view (*a*), leads into chamber *D* and is made very small at its upper end by means of a bush that has a $\frac{5}{64}$-inch opening through it. Port *e* is known as the preliminary exhaust port, as service brake applications are started by exhausting air through it from chamber *D*.

Port *g* also leads into chamber *D* and is known as the equalizing port, as its purpose in running position is to maintain in chamber *D* and the equalizing reservoir a pressure equal to that in the brake pipe, and thus keep the equalizing piston from lifting. In release position, port *g* is assisted by port *e* in maintaining an approximate equalization of pressure on piston *17*.

Port *f*, view (*b*), leads to the slide-valve feed-valve; port *l*, view (*a*), to the brake pipe; and port *k*, view (*c*), leads out through the side of the brake valve as indicated by the dotted lines. Port *k* has a shallow groove *h* leading into it. A cavity in the rotary-valve seat is indicated by *b*. Port *x* is not in the rotary seat but is in part *2* of the brake valve, view (*a*), and connects with passage *x*.

42. Ports in the Rotary Valve.—The rotary valve, view (*e*), contains three ports that pass completely through it; namely, ports *j*, *a*, and *r*. Ports *c* lead from the face of the rotary valve into an interior cavity, the extent of which outside the area of ports *c* is indicated by dotted lines. Ports *g′*, *g″*, *g‴* lead from the face of the rotary valve into this cavity. The face of the rotary valve between ports *c* is known as the bridge *o*. Groove *p* is a shallow groove cut in the face of the rotary valve.

EQUALIZING RESERVOIR AND EQUALIZING PISTON

43. Purpose of Arrangement.—The arrangement of the equalizing reservoir and equalizing piston, and the construction of the equalizing discharge valve insures (*a*) that the brake-pipe reduction with short trains shall not be so rapid as to cause the triple valves to operate in emergency; (*b*) that the engineer shall not have to operate the brake valve in a different manner with various lengths of trains in order to obtain the same brake-pipe reductions; (*c*) that with trains of any considerable length the discharge of brake-pipe air shall be closed off gradually so as to prevent the brake-pipe pressure from rising near the engine and releasing the head-end brakes thereby causing severe shocks due to running out of slack.

The gradual discharge of brake-pipe air to the atmosphere when the equalizing piston rises and unseats the equalizing discharge valve *E* is due (*a*) to the taper on the valve, the effect of the taper being to give a small port opening when the piston first begins to rise, the opening gradually increasing as the piston rises; (*b*) to the retarding effect produced on the flow of brake-pipe air by the shape of the passage in the service-

exhaust fitting; and (*c*) to the volume of the equalizing reservoir being such in connection with the size of the preliminary exhaust port *e* as to produce a reduction of pressure in the reservoir of 20 pounds in about 5 or 6 seconds.

44. The reason why the brake valve does not have to be operated differently with trains of different lengths to obtain similar brake-pipe reductions is that the volume of chamber *D* and the equalizing reservoir from which the air is first drawn does not change, and it therefore requires the same time to make a given reduction of pressure in this reservoir through the preliminary exhaust port *e* on both long and short trains. However, the time required to make a reduction in brake-pipe pressure corresponding to that made in chamber-*D* pressure increases with the length of the train, the exhaust from the brake pipe continuing longer as the length of the train increases, for the volume of air to be discharged is greater.

The discharge of the brake pipe is stopped gradually and a premature release of the head-end brakes is avoided by means of the taper on the end of the equalizing discharge valve which gradually closes the passage in the service-exhaust fitting. With a fifty-car train, the air is reducing at the engine about 5 pounds faster than at the rear of the train, but the gradual closing, in part accomplished by the tapered tip, reduces this difference so that there is no appreciable rise in brake-pipe pressure when the valve is seated.

45. The short straight section below the tapered portion of the tip insures a constant size of opening for the discharge of brake-pipe pressure in the event of a change in the lift of the equalizing piston. The extent of the opening is then kept equal to the circular space between the straight part of the extended tip and the passage it extends into; and therefore any variation in piston lift that may occur because of change in thickness of the projecting part of gasket *32* through the effects of moisture, oil, and heat, will not affect the size of the discharge opening.

46. The object of bead *18* on the equalizing piston, Fig. 8 (*a*), is to indent the leather gasket *32* during service

brake applications on long trains, and thus assist the packing ring in making a better joint between the brake pipe and chamber *D*. The bead also enlarges the area of the piston exposed to chamber-*D* air when the piston is seated against the gasket; for, if the bead were absent and the top of the piston made flat, the area exposed to the downward pressure of the equalizing-reservoir air would be so much less than that exposed to the upward pressure of the brake-pipe air as to require the brake-pipe pressure to get materially lower before the piston could be forced away from the leather gasket *32*. Then, as soon as the joint would be broken, the full area of the top of the piston would be exposed and the piston would be driven down suddenly and some of the head brakes would release.

47. The brake valve is called an equalizing-discharge valve, because during service brake applications it permits brake-pipe air to escape in such a way that the brake-pipe pressure is practically equal throughout the brake pipe when the exhausting of air stops. The brake valve is said to be automatic, as the movement of the equalizing piston and equalizing discharge valve in stopping the discharge of brake-pipe air occurs automatically, and is beyond the control of the engineer after the operation has been started by a predetermined reduction made in chamber-*D* pressure above the piston.

The equalizing reservoir serves merely to enlarge the capacity of chamber *D* of the brake valve. Placing the reservoir outside the brake valve and conecting the two by a pipe, simplifies the construction of the brake valve to a much greater extent than making a brake valve with chamber *D* of the required volume. The equalizing reservoir has outside dimensions of 10 inches and 14½ inches and has a capacity of 812 cubic inches.

48. The flow of air through the ports in the rotary valve and its seat in the different positions of the brake valve, can be more easily understood and remembered by considering the equalizing piston, Fig. 9, as the operation of the brake valve centers around this one part.

In full release position of the brake valve, the passage of air must be such as to prevent the pressure in the brake pipe

from increasing faster than that in chamber *D*, otherwise the equalizing piston would be forced upwards and permit the escape of brake-pipe air, as with a lone engine or a very short train. In running position, the pressure must be maintained equal on each side of the piston, in order to have the piston respond instantly to a reduction in chamber-*D* pressure when the rotary valve is moved to service position. In this position, the pressure on the piston must be unbalanced in order to cause the brake-pipe pressure to reduce; therefore the ports in the

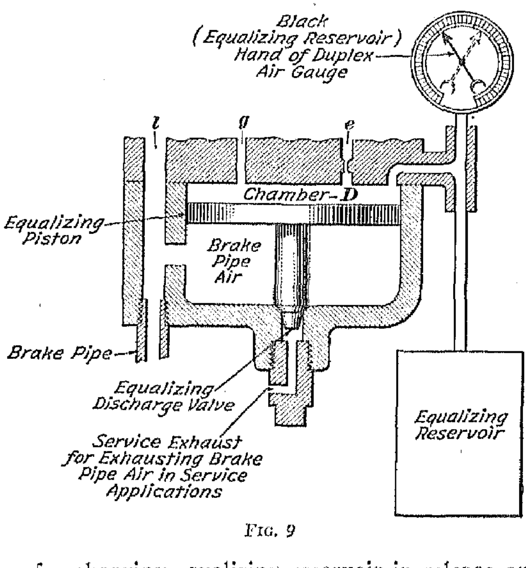


FIG. 9

Port *g* for charging equalizing reservoir in release and running positions.

Port *e*, preliminary exhaust port for exhausting air from equalizing reservoir in service position.

Port *l* for charging brake pipe in full release and running positions and exhausting air from brake pipe in emergency.

rotary valve and seat must register accordingly. In lap position, an approximate equalization of pressure is maintained on both sides of the equalizing piston. In emergency position, the equalizing piston does not operate, because brake-pipe air is exhausted from beneath the piston faster than the equalizing-reservoir air is discharged from above it.

OPERATION OF G-6 BRAKE VALVE

49. In studying the text pertaining to the operation of the G-6 brake valve, reference should be made to the cuts of the brake valve shown in Figs. 8 and 10.

50. Full Release Position.—Full release position of the brake valve is provided for promptly raising the brake-pipe pressure for the purpose of releasing the brakes and recharging the auxiliary reservoirs, after the pressure has been depleted by brake applications. This position is also used for charging the brake pipe and auxiliaries when the engine is first coupled on. The brake valve, when in full release position, connects the main reservoir directly with the brake pipe and the equalizing reservoir.

51. Reference should be made to the sectional view of the engineer's brake valve shown in Fig. 8 (*a*). It will then be noted that port *j* registers with port *e*, port *a* with cavity *b*, port *g'* with port *g*, and cavity *c* connects cavity *b* and port *l*. Main-reservoir air then passes through ports *j* and *e* to chamber *D* and the equalizing reservoir, through port *a*, cavity *b* and *c* to port *l* and the brake pipe, and through cavity *c* and ports *g'* and *g* to chamber *D* and the equalizing reservoir.

The warning port *r* is drilled through the rotary valve in such a position that when the valve is in full release position the port is directly over the exhaust port *k*. The resulting blow of main-reservoir air warns the engineer of the brake-valve position, for if the brake valve is left in full release position long enough the brake pipe will be overcharged, and a brake-pipe pressure corresponding to the setting of the governor, or 90 pounds, will finally be obtained. As the slide-valve feed-valve is held closed by a brake-pipe pressure greater than its adjustment, or 70 pounds, when the brake valve is moved to running position, the feed-valve can not open until leaks reduce the brake-pipe pressure below 70 pounds and the unsupplied leakage of air from the brake pipe will cause the brakes to apply.

52. Running Position.—The purpose of running position is to maintain automatically the pressure in the brake pipe

at a predetermined amount by supplying ordinary brake-pipe leakage, and to permit of the accumulation of excess pressure in the main reservoir when the brakes are not being used. Running position also completes the recharging of the brake pipe after the brake-valve handle is brought from release to running position.

The automatic control of the passage of air from the main reservoir to the brake pipe in running position is accomplished by the feed-valve, which closes and breaks the communication between the main reservoir and the brake pipe when the latter is charged to the desired pressure, and opens when leakage *reduces brake-pipe pressure slightly below the pressure desired.* The balance or equalization of pressure required for the prompt operation of the brakes when necessary, is maintained in the brake system in running position of the brake valve, as the brake pipe, chamber *D*, the equalizing reservoir, and the auxiliary reservoirs are all kept at the same pressure. In running position, the brake valve connects the main reservoir to the brake pipe and to the equalizing reservoir through the feed-valve.

53. Reference should be made to the sectional cuts of the brake valve shown in Fig. 8, views (*b*) and (*c*). It will then be noted that port *j* registers with port *f*, and port *g'* with port *g*. Main-reservoir air then passes through ports *j*, *f*, and *f''* and enters the feed-valve and is there reduced to the desired brake-pipe pressure. The air leaves the feed-valve through port *i*, and passes through port *i'* to the brake pipe at *l'*. Brake-pipe air enters cavity *c* from port *l* and passing through port *g'* and *g* charges chamber *D* and the equalizing reservoir. The pressure on each side of the equalizing piston is therefore maintained equal, as well as the pressures on each side of the triple pistons, and these parts will respond promptly to a difference of pressure when the brakes are to be applied.

The flow of air through the feed-valve continues until the pressure in the brake pipe becomes equal to the adjustment of the feed-valve, after which the feed-valve closes and will not open again until brake-pipe leaks reduce the pressure in the brake pipe below the desired amount.

54. Service Position.—The purpose of service position is to open the service exhaust port of the brake valve gradually, and to close it gradually and automatically, thus making the

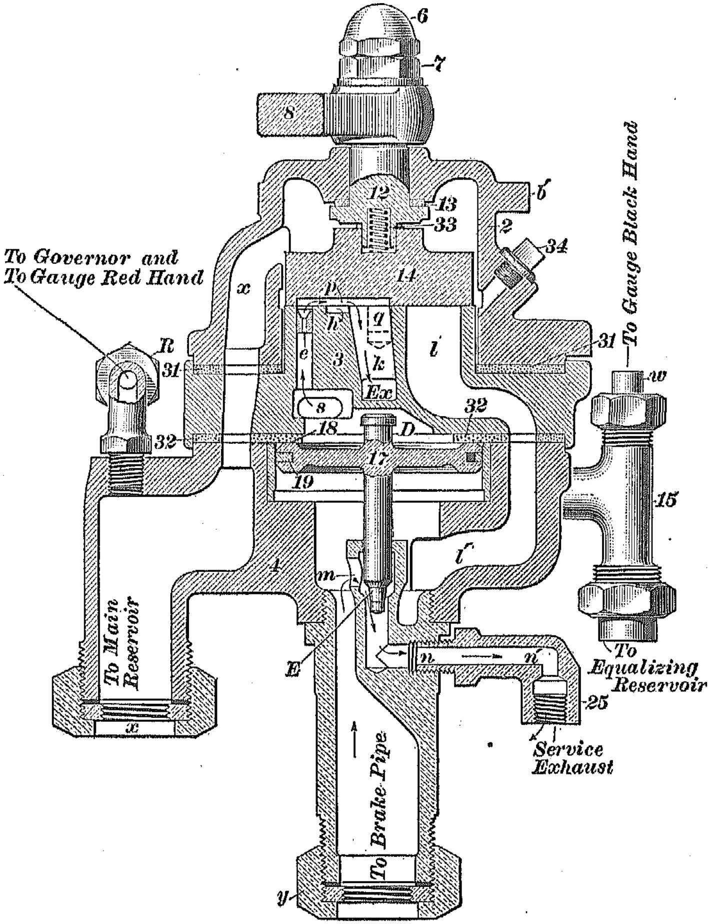


FIG. 10

brake-pipe reduction in the proper manner for service braking. The brakes are applied by placing the brake-valve handle in service position until the desired reduction has been made as indicated by the equalizing-reservoir pressure hand of the air

gauge, and then returning the handle to lap position. This operation reduces the pressure in the equalizing reservoir and causes a corresponding reduction in the brake-pipe pressure and thus applies the brakes. Therefore, in service position the rotary valve connects the equalizing reservoir to the atmosphere and thereby causes the equalizing discharge valve to open the brake pipe to the atmosphere.

55. In service position, as shown by the view in Fig. 10, groove *p* in the rotary valve connects port *e* with groove *h* which leads into port *k*. The air from chamber *D* and the equalizing reservoir then passes through port *e*, grooves *p* and *h* to port *k* and to the atmosphere at *Ex*, the discharge of air continuing until the brake valve is placed in lap position. The reduction of pressure in chamber *D* causes the equalizing piston *17* to be raised by the now greater brake-pipe pressure beneath it, and the taper on the equalizing discharge valve gradually opens passage *n n′* and permits brake-pipe air to pass through port *m* to the atmosphere at the service exhaust. The discharge of air continues until the pressure in the brake pipe is reduced slightly below the pressure retained in chamber *D*, after which the slightly greater pressure above the equalizing piston forces it down and the tapered portion of the equalizing discharge valve gradually stops the exhausting of brake-pipe air.

The time required to make a given reduction in chamber *D* from a given pressure is constant, a reduction of 20 pounds from an initial pressure of 70 pounds requiring from 5 to 6 seconds; but the time required to make an equal reduction of brake-pipe pressure increases with the volume of the brake pipe; and, with trains of considerable length, the discharge of brake-pipe air continues for some time after the brake-valve handle has been returned to lap.

The reduction in brake-pipe pressure following service position of the brake valve causes the triple valves to move to service position and apply the brakes by venting auxiliary-reservoir air to the brake cylinders. After the equalizing discharge valve seats, the triple pistons will move their graduating valves to lap position and close the communication between the auxiliary

reservoirs and the brake cylinders, the lapping action beginning at the head end and continuing back to the rear of the train.

56. Lap Position.—The purpose of lap position after service position is to hold the brakes applied, as it prevents any air from entering or exhausting from the brake pipe, and allows main-reservoir pressure to increase to the maximum when a duplex governor is used, thereby quickening the release and recharge. Lap position is also used to save main-reservoir air when a break-in-two, a burst hose, or other cause results in an open brake pipe.

In lap position, groove *p*, Fig. 10, in the rotary valve no longer connects port *e* with groove *h*, and the exhausting of equalizing-reservoir air is prevented. As already explained under Service Position, brake-pipe air continues to escape at the service exhaust until the pressure in the brake-pipe reduces slightly below the pressure retained in chamber *D*, after which the equalizing piston moves down and seats the equalizing discharge valve. The brake valve may be moved to service and back to lap as often as the conditions governing the stop require, but the brake-pipe pressure must not be reduced below the equalizing pressure of the auxiliary reservoirs and brake cylinders, which is 50 pounds when the initial brake-pipe pressure is 70 pounds.

57. Emergency Position.—Emergency position is provided to make the sudden and heavy brake-pipe reduction necessary to bring about the quick-action operation of the triple valve, as a quick reduction of brake-pipe pressure cannot be made through the service-exhaust fitting when the equalizing piston is in proper condition. In emergency position, the rotary valve is used to connect both the brake pipe and the equalizing reservoir direct to the atmosphere through the direct-exhaust port *k*, Fig. 10.

58. By referring to the views shown in Fig. 8 (*c*) and (*e*), it will be seen that ports *c* in the rotary valve in connection with interior cavity *c* connect the direct-application and supply port *l* with the direct-application and exhaust port *k*. Brake-pipe air

then flows to the atmosphere through port *l*, ports and cavity *c*, and port *k*. As these ports are large, the sudden reduction in brake-pipe pressure, necessary to secure quick action of the nearest triple valve and start serial action, will result.

In emergency position, all of chamber-*D* pressure will be discharged to the atmosphere, as groove *p* connects port *e* with groove *h*, as in service position. The principal reason for exhausting chamber-*D* air in emergency is to have the black hand of the air gauge show the rapid fall in the brake-pipe pressure that occurs at this time. Were the air not exhausted from this chamber, the black hand would fall slowly and would not correspond with brake-pipe pressure, because the air in chamber *D* would leak slowly into the brake pipe by the equalizing-piston packing ring. The equalizing piston *17* does not rise at this time, as brake-pipe air escapes more quickly below the piston than from chamber *D* above it.

59. Excess Pressure.—Excess pressure is the amount of pressure in the main reservoir over that in the brake pipe, so long as the pressure in the brake pipe has not been reduced below the equalizing point of the auxiliary reservoirs and brake cylinders. Excess pressure in combination with large main-reservoir capacity insures a prompt release of the brakes and the recharging of the brake system, and it also prevents the brakes from being applied by the use of air sanders and other air-using devices, or by a governor that fluctuates in its regulation of pressure.

Excess pressure has uses in addition to those given. One is to operate the feed-valve. At least 20 pounds of excess pressure is required to insure proper operation of the feed-valve, as a pressure of about 11 pounds is necessary to compress the piston spring of a modern feed-valve to full open position. Another use of excess pressure is to prevent the operation of air sanders and other air-using devices other than the air brakes, and to prevent a governor that fluctuates in its regulation from causing the brakes to apply.

60. The amount of excess pressure varies with brake operation and may be divided into the excess pressure carried

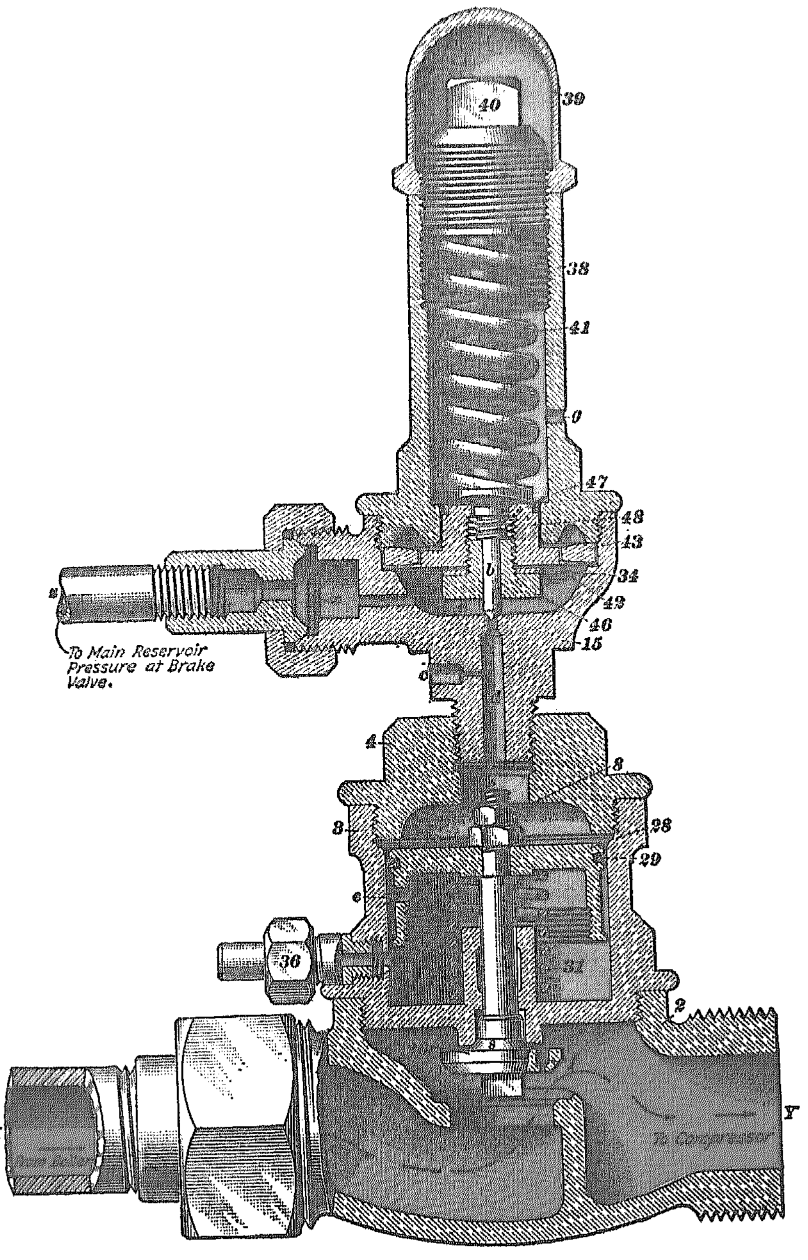
when the brakes are not being operated and the excess pressure obtained when the brakes have been applied. The amount of excess when the automatic brake valve is in running position is spoken of as the *excess pressure carried,* and is then the difference between the regulation of the low-pressure governor head and the feed-valve. The excess pressure obtained varies with the brake-pipe reduction, and the time the valve is held on lap, and when at its maximum is the difference between the highest main-reservoir pressure, as regulated by the high-pressure governor head, and the brake-pipe pressure when reduced to the point necessary to obtain a full-set brake.

For example, assume a governor to have the low-pressure head set at 90 pounds, and the high-pressure head set at 110 pounds, and that the feed-valve is adjusted for a brake-pipe pressure of 70 pounds. In running position, the excess pressure carried is 20 pounds. Reducing the brake-pipe pressure 20 pounds will make the excess pressure 40 pounds, and if the brake valve is left on lap until the compressor is stopped by the high-pressure governor head, the excess pressure obtained will be the difference between 110 and 50, or 60 pounds, which is the maximum excess pressure that can be obtained with the pressure mentioned. The governor arrangement with modern brake equipments is designed to increase the excess pressure after the brakes have been applied.

STEAM COMPRESSOR GOVERNORS

61. Purpose.—The purpose of the steam compressor governor is to stop the compressor automatically by shutting off the steam supply to it when the main-reservoir pressure reaches a predetermined point, and to start the compressor again when the main-reservoir pressure falls below the predetermined point.

62. Description.—Fig. 11 is a sectional view of a type S single-pressure governor, and it gives, as the name implies, a single main-reservoir pressure for all positions of the brake valve. The principles of operation and construction of all



BB 514B 2511

Fig. 11

compressor governors are similar, the different types differing only in the method of piping and the manner in which the parts are assembled. A description of the operation of the type S governor will therefore apply to all other types.

The names of the parts of the governor as shown in Fig. 11 are as follows: *2*, steam-valve body; *3*, cylinder body; *4*, cylinder cap; *26*, steam valve; *28*, piston, with packing ring *29* and piston spring *31*; *36*, drip pipe; *15*, diaphragm body; diaphragm complete, consisting of diaphragm nut *46*, diaphragm washer *34*, diaphragm valve *b*, diaphragm spring *47*, diaphragm spindle *48*, and diaphragm *42*, which consists of two thin sheets of brass; *43*, diaphragm ring; *41*, regulating spring; *40*, regulating nut; *39*, check nut; *38*, spring box.

63. The compressor connection to the governor is made at *Y* and the boiler connection at *X*. The pipe *z* which is connected to the air portion of the governor is connected to the brake valve at *R*, Fig. 8, view (*a*). Consequently, pipe *z*, Fig. 11, and chamber *a* always contain air at main-reservoir pressure when the compressor is operating. A strainer *x* in the pipe connection prevents dirt or scale from reaching the seat of the diaphragm valve *b*. The diaphragm *42* is secured to the diaphragm spindle *48* by the diaphragm nut *46* and the diaphragm washer *34*.

The diaphragm *42*, and therefore the complete diaphragm, is held in the diaphragm body *15* by the brass diaphragm ring *43*, which presses the upper and outer edge of the diaphragm *42* against the diaphragm body when the spring box *38* is screwed down tight. The purpose of the complete diaphragm is to transmit the air pressure exerted beneath it to the regulating spring above it, thus operating the diaphragm valve *b*. The diaphragm ring *43* is concave on both sides, which permits of the complete diaphragm being moved up and down a small amount within the opening in the ring on account of the flexibility of the brass diaphragm *42* and the concavity of the lower face of the ring. The lower end of the regulating spring *41* rests on a shoulder on the upper side of the diaphragm spindle *48*, and therefore exerts a downward pressure equal to the ten-

sion of the spring on the complete diaphragm. The upper side of the spindle and the lower side of the regulating nut *40* are stem-shaped and therefore act as guides for the regulating spring. Air pressure in chamber *a* on the lower face of the diaphragm *42* in excess of the tension of spring *41* deflects the diaphragm upwards at its center and thereby carries the complete diaphragm upwards through ring *43* and unseats the diaphragm valve *b*. Also, a decrease of pressure in chamber *a* causes the regulating spring to return the complete diaphragm back to its original position and to seat valve *b*.

The small spring *47* under the head of the diaphragm valve *b*, fits loosely where valve *b* passes through the nut *46*, and permits the valve to seat accurately and prevents lost motion vertically. The tension of the regulating spring *41* can be adjusted by the regulating nut *40* to give the main-reservoir pressure desired. The steam valve *26* is attached to the governor piston *28*, by means of its stem and locknuts *8*.

64. The stem of the steam valve *26* makes a snug fit where it passes through the cylinder body *3*, and the shoulder *s* when the valve is open, as in Fig. 11, makes a joint against the lower end of the body and thus prevents steam from leaking under piston *28*. A waste port in the piston chamber to which a drip pipe *36* is connected prevents the accumulation of any pressure, whether steam or air, below the piston *28*, which would thus prevent its downward movement; a short elbow is most always used instead of a drip pipe, as there is then less liability of freezing. When the steam valve is closed, piston *28* will be in its lowest position, and a series of small ports *e*, through the piston, one of which is shown, prevent the piston at this time from blocking the waste port and allowing steam that may leak by the piston stem to accumulate under piston *28*.

65. Vent port *c*, Fig. 11, connects the chamber *d* above piston *28* with the atmosphere at all times, and serves to vent the air quickly from above the piston, and allow the piston spring *31* promptly to open the steam valve *26* when the diaphragm valve *b* closes. It also prevents an accumulation of pressure above piston *28* in case the diaphragm valve leaks.

Port *g* in the spring box prevents the accumulation of any pressure that might leak past a cracked diaphragm. A small port *f* is drilled through steam valve *26*. This port allows a small amount of steam to the compressor during the time the valve

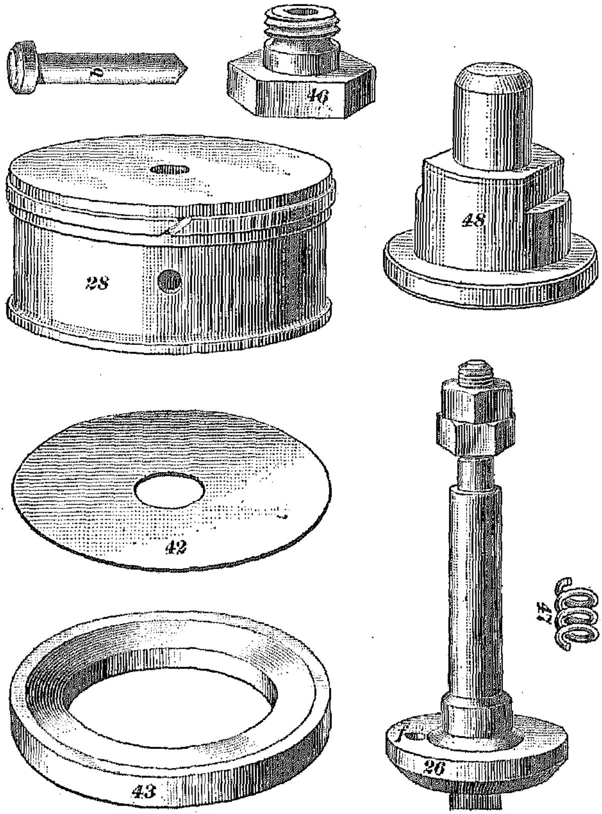


Fig. 12

is on its seat. The compressor will not then entirely stop, and will make an occasional stroke which prevents condensation from washing out the lubrication in the steam end.

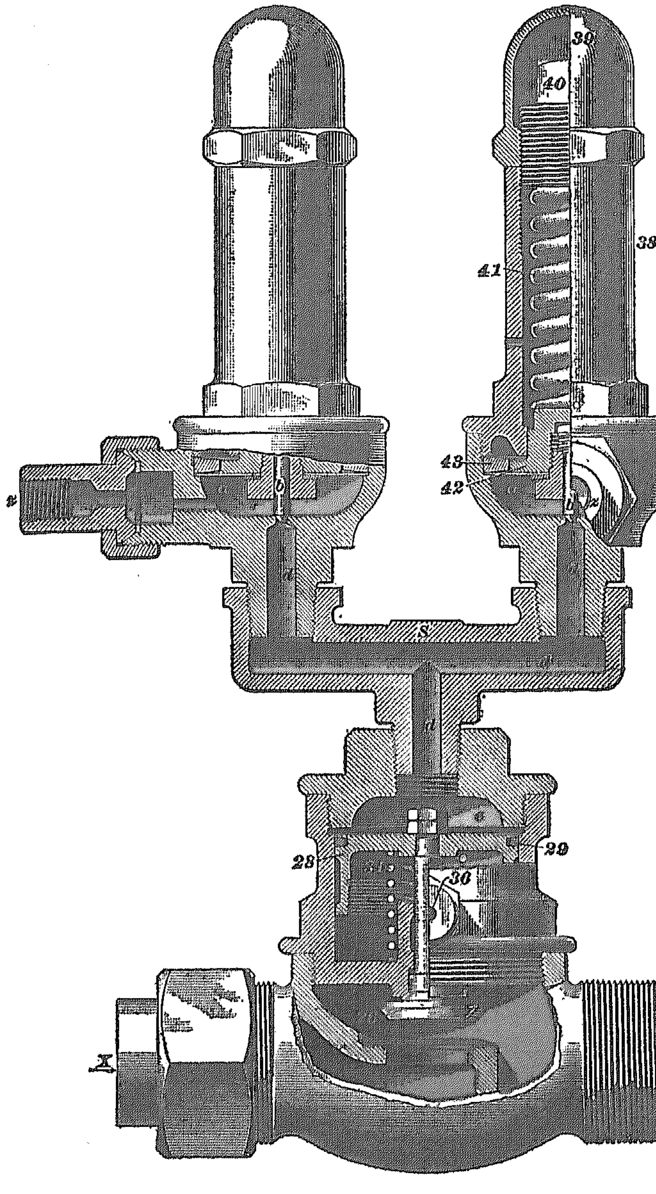
66. Parts of Governor.—Fig. 12 shows the parts of the complete diaphragm disassembled, consisting of diaphragm valve *b*, diaphragm spindle *48*, spring *47*, nut *46*, and dia-

phragm *42*. The flat part of the diaphragm spindle is used to hold the spindle stationary when disassembling the complete diaphragm. Fig. 12 also shows the diaphragm ring *43*, the governor piston *28*, and the steam valve *26*. The two latter parts are shown disassembled. The diaphragm ring is made concave on both sides so that it cannot be placed in the spring box the wrong way.

OPERATION OF GOVERNOR

67. The normal position of the parts when no pressure is present or when the governor is not controlling the compressor, is as shown in Fig. 11, the diaphragm valve *b* being seated, and the steam valve *26* being held open by spring *31*. The regulating spring *41* is, as a general practice, adjusted so that it will transmit a pressure of 90 pounds against the top side of diaphragm spindle *48*. When the compressor is in operation, the pressure in the main reservoir, and consequently in chamber *a* of the governor, increases until a pressure of 90 pounds is reached. When the pressure against diaphragm *42* in chamber *a* slightly exceeds the pressure exerted by the regulating spring *41* on the diaphragm spindle *48*, the diaphragm *42* is raised, carrying the diaphragm valve *b* with it. The air in chamber *a* passes by the unseated diaphragm valve *b*, down into chamber *d* on top of the piston *28*, forcing it down and thus seating the steam valve *26*. As long as main-reservoir pressure remains at 90 pounds, the diaphragm *42* will hold the pin valve *b* from its seat, and the pressure in chamber *d* will hold the steam valve *26* to its seat. As long as diaphragm valve *b* is unseated, there will be a small amount of air escaping at vent port *c*, but as the inner end of this port is very small, air can pass by the diaphragm valve *b* faster than it can escape through port *c*.

68. When the main-reservoir pressure falls below 90 pounds, the thrust of the spring *41*, Fig. 11, on the diaphragm spindle *48* tending to force down the diaphragm *42* will overcome that of the air in chamber *a* tending to force it up; consequently, the diaphragm will move downwards and thus seat



BB 514B 2511

FIG. 13

the diaphragm valve *b*. This shuts off the air supply to chamber *d*, and the air confined therein by the closing of the diaphragm valve escapes to the atmosphere through the relief port *c*. The pressure now being removed from above the piston *28*, the spring *31*, aided by the steam under valve *26*, forces the piston upwards, unseating valve *26* and allowing steam to pass through the governor to the compressor. The piston *28* is made enough larger than the steam valve *26* to enable a moderate air pressure easily to hold valve *26* to its seat against the combined upward force of the steam pressure under the valve and the push of spring *31*.

69. Type S D Governor.—The duplex governor as shown in Fig. 13 is known as type S D, and consists of two air portions each similar to the air portion used with the type S governor, and connected by a Siamese fitting *S* to a steam portion also similar to the one used with the type S. The ports *d* in the fitting *S* permit air from either of the diaphragm chambers *a* to pass down on top of piston *28* when either one of the diaphragm valves *b* is unseated. The duplex governor is then merely a combination of two type S governors and operates in the same manner, since only one head operates at a time. The maximum or high-pressure top on the left is usually adjusted for 120 pounds and the right or low-pressure top for 90 pounds, or 20 pounds in excess of the amount for which the slide-valve feed-valve is adjusted.

The use of the duplex governor permits of duplex main-reservoir control, as it enables a moderate main-reservoir pressure to be carried when the brakes are not being operated, and the accumulation of a high main-reservoir pressure when the brakes are applied.

The advantage of duplex main-reservoir control is that the compressor operates against a moderate main-reservoir pressure when the brake valve is in running position and the brakes inoperative. At this time, sufficient excess pressure is maintained to operate the feed-valve and supply auxiliary air devices on the engine, and excessive wear and heating of the compressor due to high compression is then avoided. However, when

the brakes are applied and the brake valve is lapped, the main-reservoir pressure, and therefore the excess pressure, increases, which permits of a prompt release of the brakes and recharge of the brake system.

70. Piping Arrangement. — It is unnecessary to explain the operation of the duplex governor in detail as the operation of either diaphragm portion in stopping and starting the compressor is the same as the type S. It is therefore only necessary to explain the piping arrangement which enables the low-pressure head to control the compressor in full-release and running positions, and the high-pressure head to control in lap, service, and emergency positions.

71. The piping arrangement necessary to secure duplex main-reservoir control is shown in Fig. 14.

The high-pressure governor head is connected by a pipe to the brake valve at *R*, the same as the type S governor, and this pipe therefore always contains air at main-reservoir pressure. The low-pressure head is connected by a pipe to a port *f'* in the brake valve, this port being drilled into passage *f* that leads to the feed-valve from the rotary-valve seat.

In running position, the air in passage *f* and port *f'* is at main-reservoir pressure, and when it reaches 90 pounds, the governor head set for the lower pressure will operate and stop the compressor. The low-pressure governor head will also stop the compressor in release position, if the brake valve should be left in this position until the pressure in the brake pipe is increased to 90 pounds, even though the rotary valve has the upper end of port *f* closed, for passage *i* in the feed-valve is always connected to the brake pipe, and the brake-pipe pressure will unseat the supply valve *55* in the feed-valve and enter passage *f*, and thus cause the low-pressure head of the governor to operate.

In lap, service, and emergency positions, the air in passage *f'* reduces to brake-pipe pressure, and will be kept at this amount, as the rotary valve then has port *f* in the rotary-valve seat closed. The low-pressure head is then cut out and the compressor continues to work until stopped by the high-pressure

head. The low-pressure governor head is usually adjusted to give 20 pounds more pressure in the main reservoir and the high-pressure governor head 40 pounds more, than in the brake pipe. Each governor head should be adjusted in one of the positions of the brake valve in which it controls the compressor. The low-pressure head should therefore be adjusted with the brake valve in running position, and the other head with the brake valve on lap.

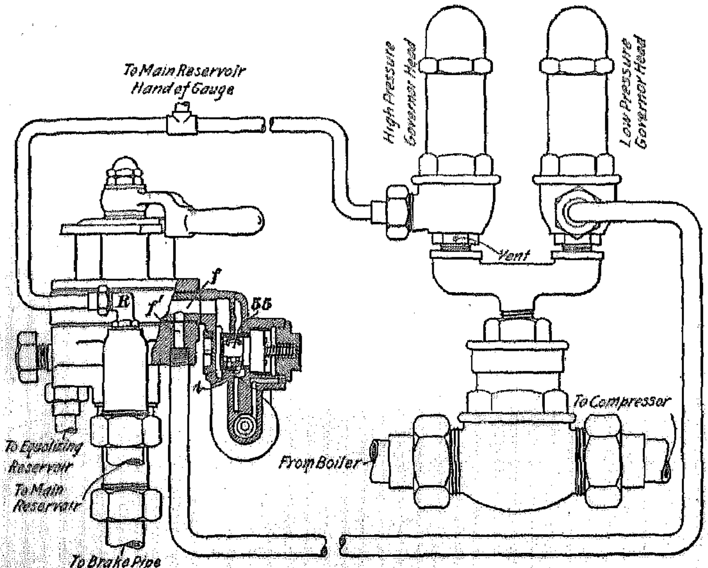


FIG. 14

SLIDE-VALVE FEED-VALVE

72. Purpose of Feed-Valve.—The purpose of the slide-valve feed-valve is to maintain automatically the brake-pipe pressure at the predetermined amount when the automatic brake valve is in running position, and thus prevent brake pipe leaks from applying the brakes. The slide-valve feed-valve closes communication between the main reservoir and the brake pipe when the pressure in the brake pipe has increased to the amount the valve is adjusted for, and opens communication between the main reservoir and the brake pipe again when

leakage reduces the pressure in the brake pipe below the adjustment of the feed-valve.

It is important that the slide-valve feed-valve be maintained to operate on a less difference of pressure than that required to move the triple pistons of the triple valves; otherwise brake-pipe leaks would have a tendency to cause the brakes to creep on.

The C-6 single-pressure feed-valve is regularly furnished with the A-1 engine equipment.

73. External Construction.—Fig. 15 is an exterior view of the C-6 single-pressure feed-valve as seen from the front, and Fig. 16 shows this valve as viewed from the rear. The valve consists of two parts *X* and *Y*. Part *X* contains the valve arrangement that controls the supply of air to the brake pipe and is therefore known as the supply portion. Part *Y* is used to regulate the brake-pipe pressure and is therefore known as the regulating portion.

74. Diagrammatic Views of Feed-Valve.—As part *Y* of the feed-valve stands at right angles to part *X*, it is difficult to show all the interior parts of the feed-valve in one view. Therefore two diagrammatic views of the feed-valve are shown in Figs. 17 and 18, part *X* being shown turned to the left until it stands in the same plane as part *Y*. The feed-valve is shown in open position in Fig. 17 and in closed position in Fig. 18.

75. Operation of Slide-Valve Feed-Valve.—It will be assumed in this study of the operation of the feed-valve that the compressor has just been started, and that the brake-valve handle is in running position. In the absence of air pressure, the spring *58* will have forced the piston *54* and supply valve *55* to their normal, or closed, position, thereby closing port *b* as in Fig. 18. The regulating valve *59* will be held in its normal, or open, position by diaphragm *57* and spring *67*, as shown in Fig. 17.

As soon as pressure begins to accumulate in the main reservoir, air enters passage *f″*, Fig. 17, from the brake valve and begins to leak past piston *54* into chamber *E*. As the regulating valve *59* is held open, the light leakage by the piston passes

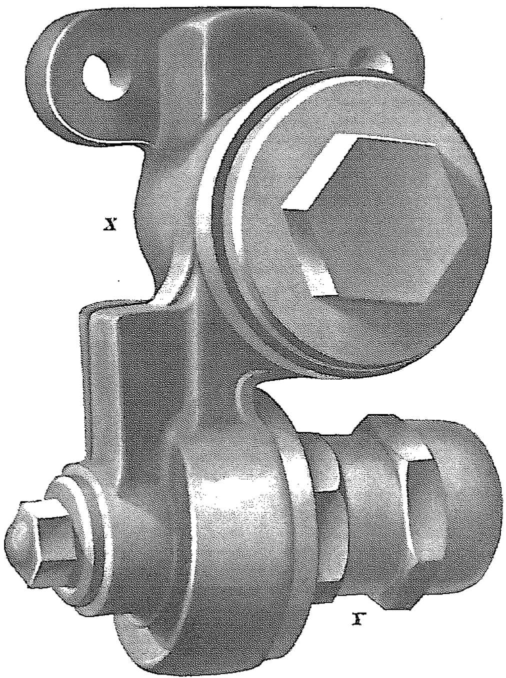


Fig. 15

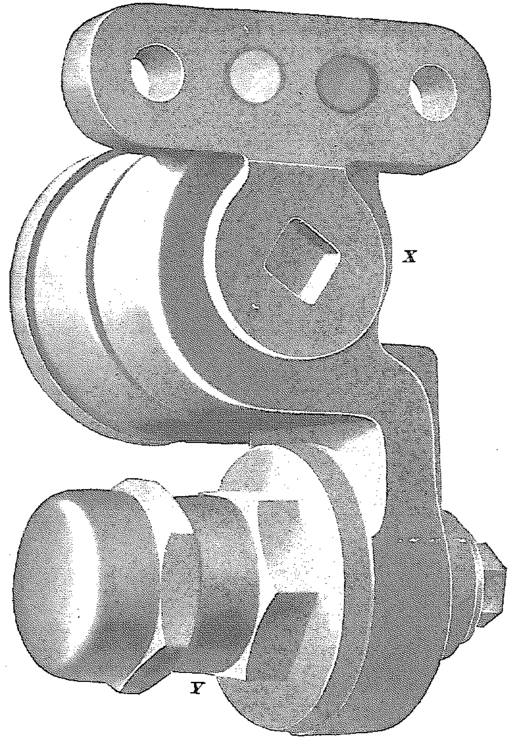
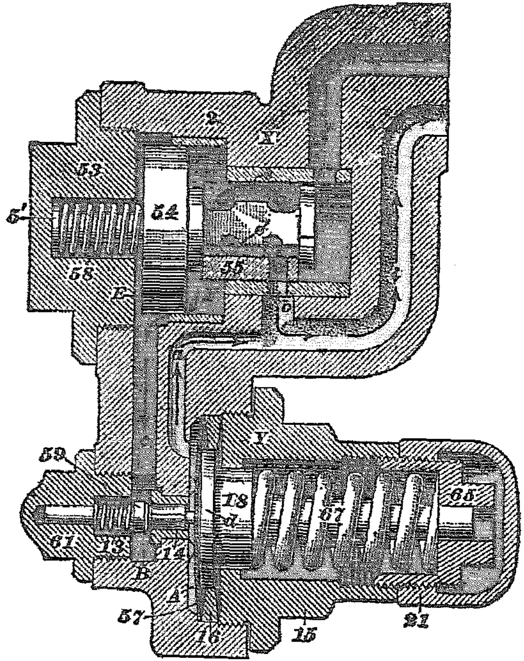


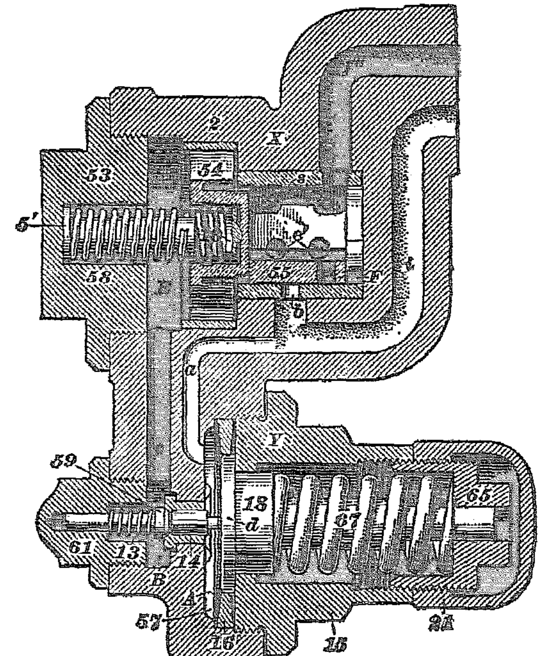
Fig. 16

BB 514B 2511



53
5'
54
58
E
2
X
8
55
b
a
59
61
13
14
B
A
57
16
18
d
67
Y
65
15
21

Fig. 17



53
5'
58
54
2
X
8
55
F
b
a
E
59
61
13
14
B
A
57
16
18
d
67
Y
65
15
21

Fig. 18

directly to the brake pipe by way of passage *c*, regulating valve *59*, and passage *a* and *i*. When sufficient pressure has been accumulated in the main reservoir and in chamber *F*, to overcome the tension of spring *58*, the piston *54* and supply valve *55* will be forced to the left, or open, position, and the brake pipe will be supplied with air through ports *e′* and *e* in the supply valve, port *b*, and passage *i*.

The pressure required to compress spring *58* is indicated on the air gauge by the difference between the two hands, when the brake-pipe pressure is being raised in running position.

76. When the passage of main-reservoir air into the brake pipe has raised the pressure to 70 pounds or to the adjustment of the regulating spring *67*, Fig. 17, the brake-pipe pressure in chamber *A* forces diaphragm *57* to the right, and permits spring *13* to seat the regulating valve *59*. As the leakage by piston *54* cannot escape into the brake pipe when the regulating valve is closed, the pressure in chamber *E* quickly equalizes with that in chamber *F* on its opposite face. Spring *58* then forces piston *54* and supply valve *55* to the right as shown in Fig. 18, and cuts off the admission of air through port *b* to the brake pipe.

77. The feed-valve remains in the closed position until the brake-pipe pressure is reduced below 70 pounds. As chamber *A* is always in direct communication with the brake pipe, the pressure in chamber *A* also reduces with the brake-pipe pressure. The regulating spring *67* then expands and the diaphragm *57* unseats the regulating valve *59*. Communication is then established between chamber *E* and the brake pipe and results in the greater pressure in chamber *F* moving piston *54* and the supply valve *55* to open position, Fig. 17.

78. Regulation.—If the slide-valve feed-valve does not regulate the brake-pipe pressure to the proper amount, it can be made to do so by adjusting the regulating nut *65*, as follows:

If it maintains a pressure below the standard, turn the regulating nut *65* slowly until the tension of the spring *67* is sufficiently increased to give proper regulation.

If it maintains too high a pressure, place the brake valve in service position and reduce the brake-pipe pressure several pounds below standard; then turn the regulating nut *65* so as to relieve the spring *67* of a little of its tension, place the brake valve in running position, and note the pressure that is then maintained. If still too high, proceed again as above, and continue to so regulate until the feed-valve is properly adjusted.

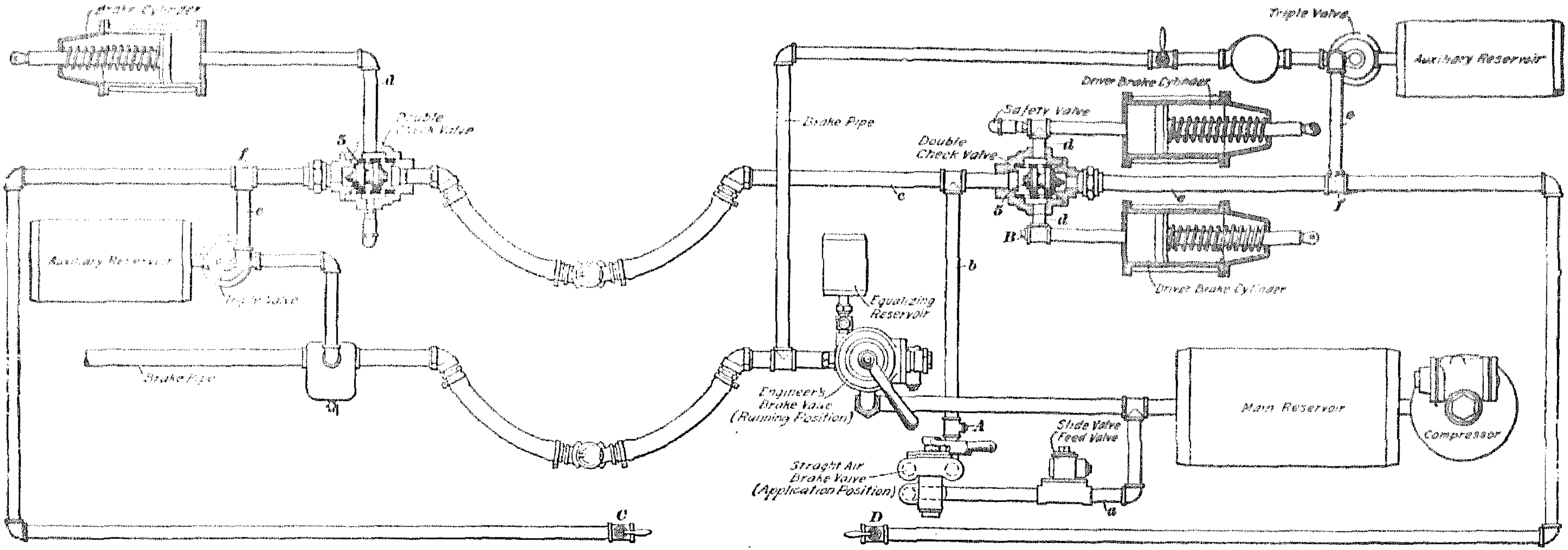
COMBINED AUTOMATIC AND STRAIGHT-AIR LOCOMOTIVE BRAKE EQUIPMENT

GENERAL ARRANGEMENT

79. The combined automatic and straight-air engine and tender brake equipment consists of the standard automatic arrangement as illustrated in Fig. 1, with the additional parts necessary for a straight-air brake on the engine and tender. The arrangement of the apparatus is such that the operation of one brake does not interfere with the operation of the other, both, therefore, being cut in at all times. The parts comprising the straight-air brake on the engine are known as schedule S W A and on the tender as schedule S W B.

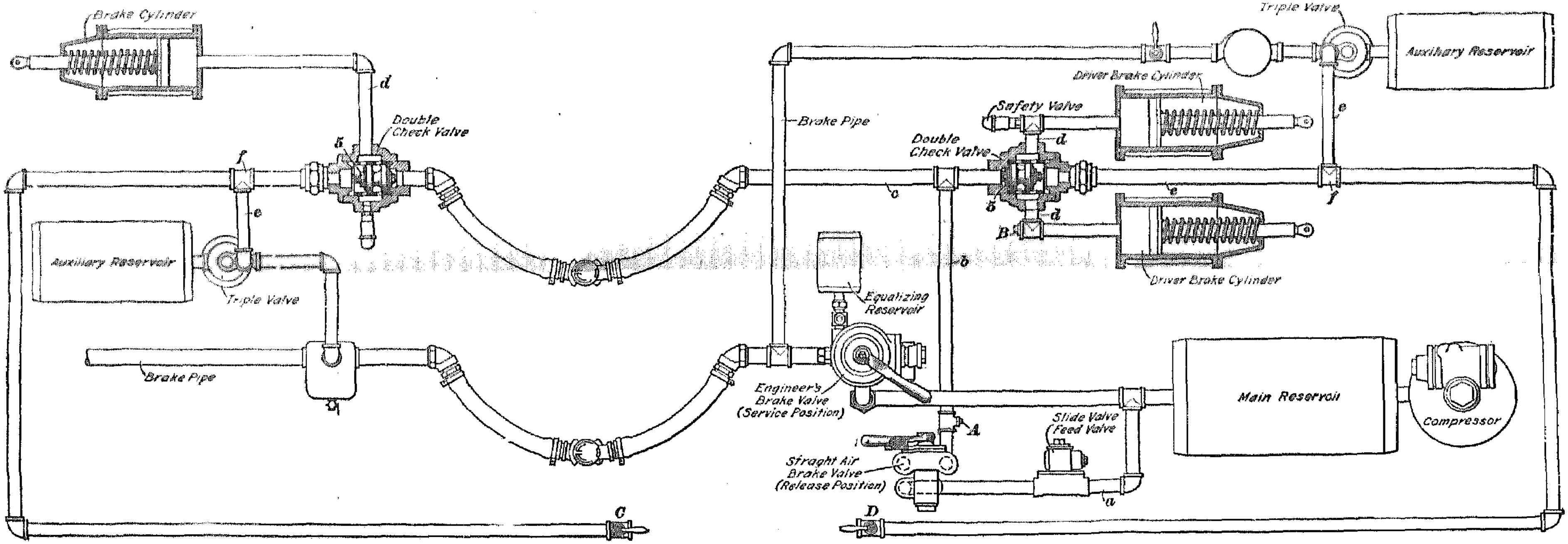
80. Figs. 19 and 20 show the general arrangement of the combined automatic and straight-air brake equipment as applied to a freight engine. Fig. 19 shows the straight-air brake applied, and Fig. 20 shows the automatic brake applied. As the automatic arrangement has already been shown, it will only be necessary to explain the arrangement of the straight-air brake, and the changes necessary to connect the straight-air brake to the automatic brake.

A pipe *a*, in which is placed a slide-valve feed-valve set at 45 pounds, leads from the main-reservoir pipe to the straight-air brake valve. A pipe *b* leads from the straight-air brake valve to a pipe *c* that connects in turn to the double check-valves on the engine and tender. The purpose of pipes *b* and *c* is to admit air to and exhaust air from the engine and tender brake



Brake Cylinder
Triple Valve
Auxiliary Reservoir
Driver Brake Cylinder
Double Check Valve
Safety Valve
Brake Pipe
Double Check Valve
Auxiliary Reservoir
Triple Valve
Equalizing Reservoir
Driver Brake Cylinder
Brake Pipe
Engineer's Brake Valve (Running Position)
Main Reservoir
Compressor
Slide Valve Feed Valve
Straight Air Brake Valve (Application Position)

FIG. 19



Brake Cylinder
Triple Valve
Auxiliary Reservoir
Driver Brake Cylinder
Double Check Valve
Safety Valve
Brake Pipe
Double Check Valve
Auxiliary Reservoir
Triple Valve
Equalizing Reservoir
Driver Brake Cylinder
Brake Pipe
Engineer's Brake Valve (Service Position)
Main Reservoir
Compressor
Slide Valve Feed Valve
Straight Air Brake Valve (Release Position)

FIG. 20

cylinders, when using the straight-air brake. Pipes *d* are attached to each side of the double check-valve on the engine and lead to the brake cylinders, and a pipe *d* on the tender connects the double check-valve to the tender brake cylinder. Pipes *e*, that ordinarily connect the triple valves to the brake cylinders on the engine and tender, connect instead with the combined equipment to the double check-valves. The double check-valves then serve to connect the automatic-brake system to the straight-air brake system.

81. If the double check-valves were not used and pipes *b*, *c*, and *e* were connected directly to the brake cylinders, the air passing from the triple valves through pipes *e* to the brake cylinders, when the automatic brake valve was in use, would pass to the atmosphere through the straight-air brake valve. Also, during straight-air brake applications, the air passing through the straight-air brake valve to pipes *b* and *c* would pass to pipes *e* and thence to the atmosphere through the triple-valve exhaust ports. The double check-valves are then necessary to prevent the air from passing out of the exhaust port of one system when the other system is being operated.

Gauge connections are provided at *A* and *B*. The brake-cylinder gauge when connected at *B* shows the driver-brake cylinder pressure in automatic as well as straight-air applications. Gauge connection *A* is provided so that the straight-air gauge connected at *B* can be tested without being removed. A ¼-inch plug is provided at *A* to permit the test gauge to be applied temporarily.

82. Cocks *C* and *D*, which are attached to piping extending to T's *f*, are provided to cut out the automatic brake on the engine and tender when descending heavy grades, where the continued use of the automatic brake would result in overheating the tires. When cocks *C* and *D* are opened, or turned at right angles to their pipes, the brakes on the engine and tender cannot be applied by the automatic brake valve, as the auxiliary air when setting the brakes passes out through the open cocks instead of passing to the brake cylinders. The auxiliary reservoir, however, will be kept recharged with those of the train.

The straight-air brake can be applied and released with cocks *C* and *D* open and thus aid in recharging the train brakes on grades without overheating the tires, as the double check-valves prevent the air that is passing to the brake cylinders from enter-

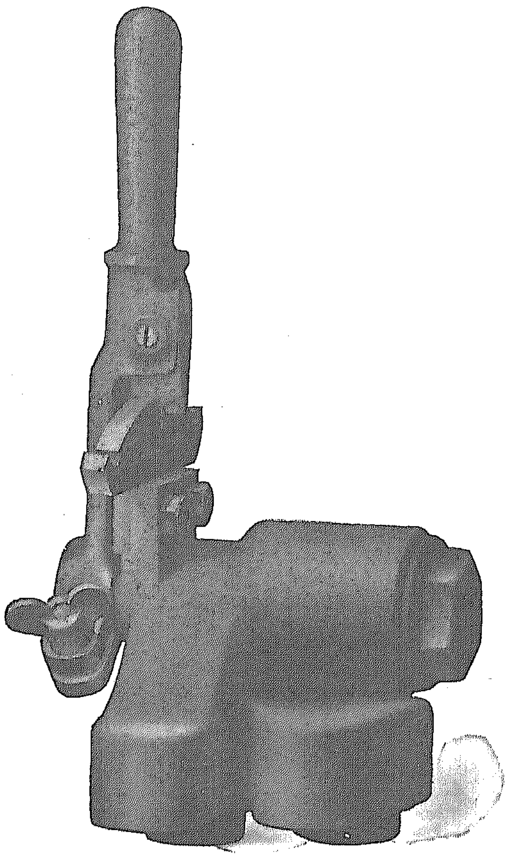


FIG. 21

ing pipes *e*. Cock *D* is also used in the event of the driving wheels sliding, as the brake can be released at once by opening this cock when it is applied by the automatic brake valve, but not when applied by the straight-air brake valve.

STRAIGHT-AIR BRAKE VALVE

83. Construction.—Figs. 21 and 22 illustrate the external construction of the S-3 straight-air brake valve, the former showing the valve in an upright position, and the latter showing a view of the bottom. The pipe from the main reservoir connects to the valve at *X*, the pipe leading to the brake cylinder connects at *Y*, and *Z* is the exhaust port. *U* and *V* are the cap nuts for the application valve *8* and the exhaust valve *9* shown in Fig. 6.

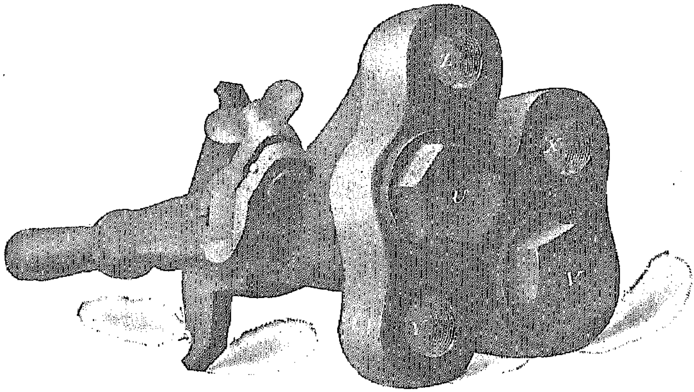


FIG. 22

Figs. 23, 24, and 25, which show the brake valve sectioned and broken away, illustrate the interior construction of the valve. The shaft *2* extends through the partition *P* and the brake-valve case, and is connected to the handle *4*, so that moving the handle rotates the shaft. To prevent leakage along the shaft past the partition *P* when the brake is applied, a specially prepared leather washer *6* is placed between the shoulder of the shaft and the partition. The shaft is then held against the washer by air pressure acting on the end of the shaft, assisted by the spring *7*; when the brake is released, the spring *7* holds the shaft against the washer.

The shaft *2* when rotated by the brake-valve handle *4* unseats the application valve *8* and the exhaust valve *9*, the valves being set off the center line of the shaft. Two slots, one of which

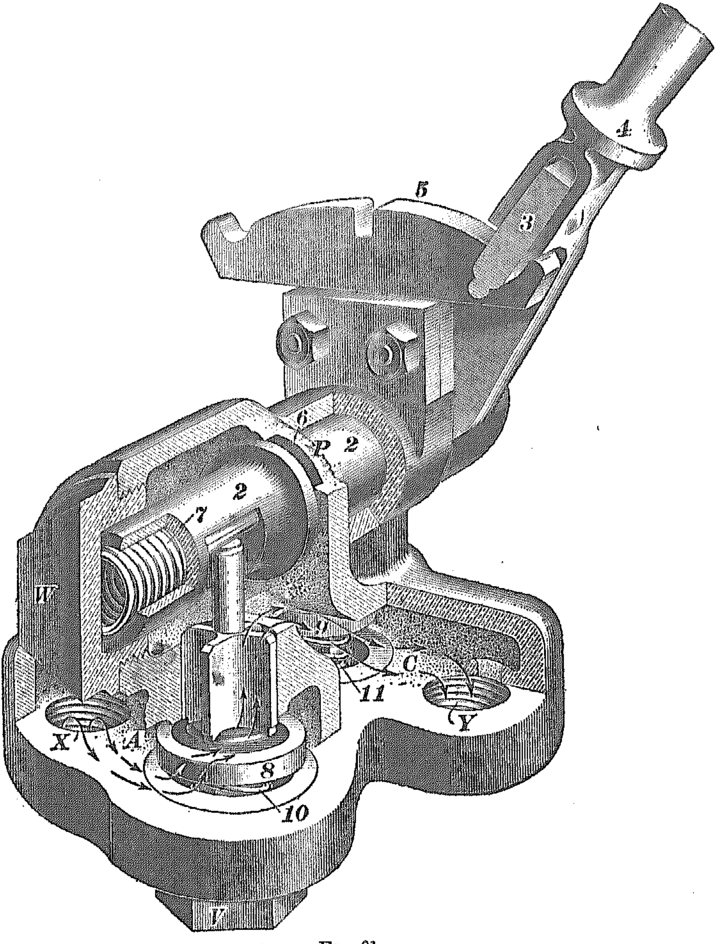


FIG. 23

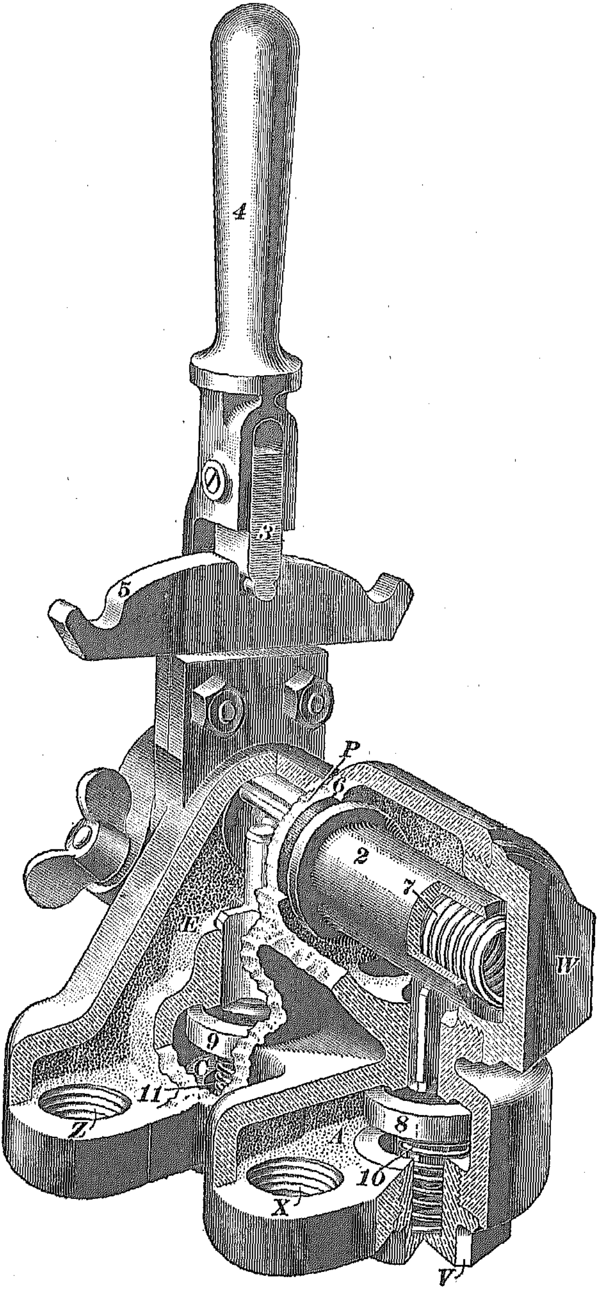


Fig. 24

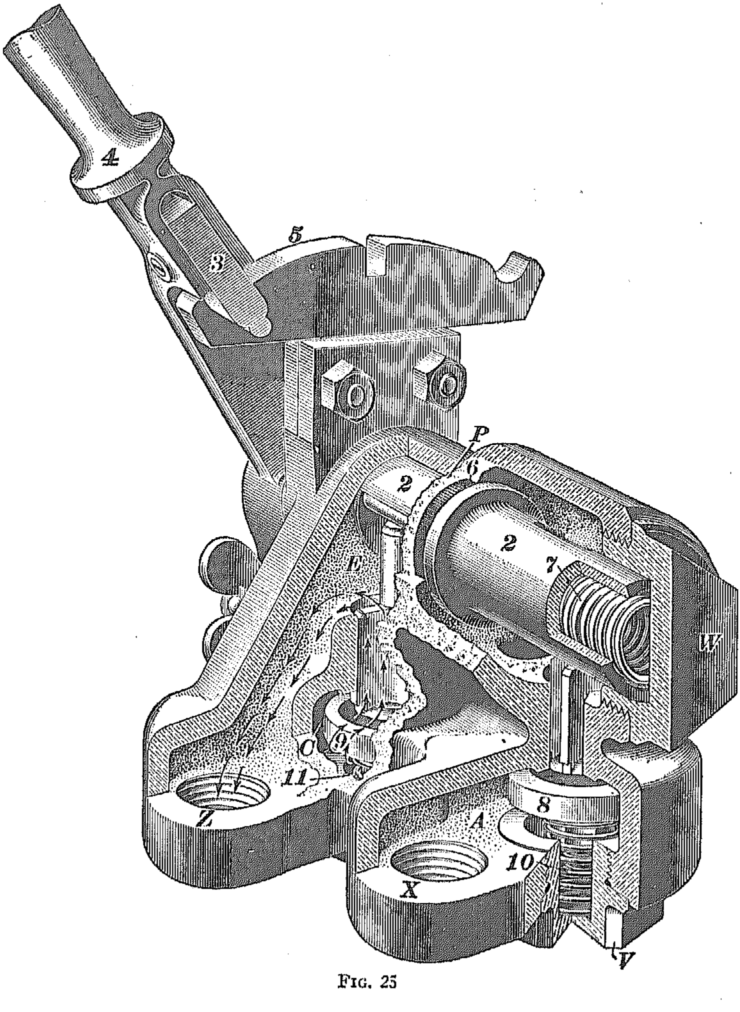


Fig. 25

is shown in Fig. 23, are cut in shaft *7* directly above each valve, and a piece of steel having a rounded flange along one edge is riveted in each slot. Application valve *8* is forced downwards and unseated by the rounded flange in the slot, which is turned against the stem of the valve when the shaft *2* is rotated by the brake-valve handle *4*. Exhaust valve *9*, Fig. 25, is unseated in a similar manner when the brake-valve handle is moved to the position shown. As the slots are cut in the opposite sides of shaft *2*, a forward movement of the brake-valve handle *4* is required to unseat valve *8*, and a backward movement to unseat valve *9*. When not being operated, the valves are held up to their seats by springs *10* and *11* beneath them and by air pressure.

Chamber *A* in the brake valve, Fig. 23, conveys air at 45 pounds pressure from port *X* to the space under application valve *8*. Chamber *C* connects the lower face of exhaust valve *9* to the brake-cylinder connection *Y*. The application valve *8* when unseated connects ports *X* and *Y*. Passage *E*, Fig. 24, serves to connect the upper face of exhaust valve *9* to the exhaust port *Z*.

84. Operation.—The straight-air brake is applied by moving the brake-valve handle *4* to application position, Fig. 23. Application valve *8* is unseated in the manner already described and air from port *X* and chamber *A* passes through to chamber *C* and out to the brake-cylinder pipe at *Y*. In this position the spring *11* and the air pressure in chamber *C* hold valve *9* up against its seat, thus preventing the escape of air at the exhaust port of the brake valve. The piston *5* in the double check-valve on the engine, Fig. 19, is forced to the right and the one on the tender is forced to the left, which permits the air to enter the brake cylinders without allowing it to pass into pipes *e* and escape at the triple-valve exhaust ports.

If the handle is left in this position, the brake-cylinder pressure will equalize with chamber-*A* pressure at 45 pounds—that being the pressure the slide-valve feed-valve is set to maintain —and no higher brake-cylinder pressure can be obtained with the straight-air brake. To make a partial application of the

brake, the handle *4* is moved to application position until the desired brake-cylinder pressure is obtained, when it is moved to lap. To increase the application, the handle is moved to application position for the proper increase, and then back to lap.

In lap position, Fig. 24, valves *8* and *9* are both closed and no air can pass from chamber *A* into the brake cylinder, or from the brake cylinder to the atmosphere through valve *9*. Valve *8* is held up against its seat by the combined efforts of spring *10* and chamber-*A* pressure, and valve *9* is held up against its seat by spring *11* and chamber-*C* pressure.

85. To release the brake, the brake-valve handle *4* is moved to release position, Fig. 25. The backward movement of the handle *4* causes the rounded flange in the slot in shaft *2* to unseat the exhaust valve *9*. The air from chamber *C* beneath the valve, and therefore from the brake cylinder, passes the unseated valve and escapes through passage *E* to the exhaust port *Z*, as indicated by the arrows. A graduated release can be made with this brake valve when desired. To partly release the brakes, the handle is first moved to release position until the desired reduction of brake-cylinder pressure is made, and then it is moved to lap.

The notches at the ends of the quadrant *5* into which the latch *3* fits, are intended to hold the handle in position against the tension of the springs *10* and *11*. If these notches become worn, the force of the spring *11* is liable to return the handle to lap position from release position.

DOUBLE CHECK-VALVE

86. Construction.—The double check-valve shown in Fig. 26 is located in the pipe between the triple valve and its brake cylinder. It is connected to the triple valve at one end. to the straight-air brake valve at the other, and to the brake cylinder at the side opening. It consists of a valve body *2* with a brass bushing *4* pressed into it, inside of which a valve *5* moves easily. On each end of valve *5* are leather gaskets *7*,

which make air-tight joints at a and b when the valve is moved against either end of the bushing *4*.

In this description of the action of the double check-valve it is to be understood that the automatic brake is released when the straight-air brake is applied, and vice versa. When the straight-air brake is used, air coming in from the brake valve at *W* will push the valve *5* into the position shown. Gasket *7* will then make a tight joint at b and prevent the escape of air at the exhaust port of the triple valve. The air will then pass through ports c to the brake cylinders.

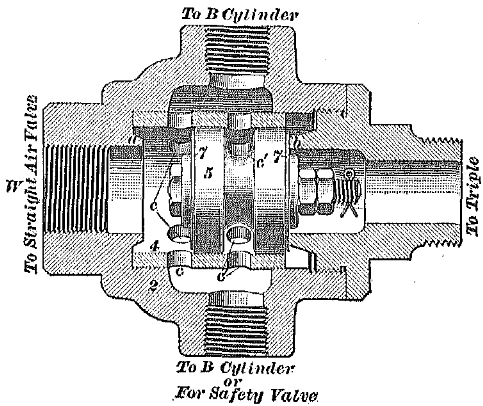


FIG. 26

When the automatic brake is applied, valve *5* moves to the other end of its travel, and gasket *7* makes a joint at a and prevents any escape of air at the exhaust opening of the straight-air brake valve; the air then passes through ports c' to the cylinders. The positions of the pistons in the double check-valves during automatic brake applications are shown in Figs. 19 and 20.

These double check-valves should always be in a horizontal position, so that they will not be moved by gravity. A double check-valve is required for each triple valve on the locomotive, one for the tender brake and one for the driver brake.

87. Instructions for Operation. — The instructions for operating the combined automatic and straight-air locomotive brake equipment are as follows:

Always keep both brakes cut in and ready for operation, unless failure of some part requires cutting out.

Carry an excess pressure of 20 pounds or more in the main reservoir, as this is necessary to insure a uniformly satisfactory operation.

88. When ample excess pressure is carried, there will be less liability of air-operated devices drawing the main-reservoir pressure below that in the brake pipe, thus causing an automatic brake application on the engine and tender. When this occurs, pressure will be trapped in pipes *e* between the triple valves and double check-valves, and will hold piston *5* of the double check-valves in the position shown in Fig. 20. When the straight-air brake valve is placed in application position, the pressure developed will move the pistons of the double check-valve in the opposite direction as shown in Fig. 19, allowing air to pass to the brake cylinders. However, when the straight-air brake valve is placed in release position, and the brake-cylinder pressure is reduced below the pressure trapped in pipes *e*, the piston *5* in the double check-valves will again move to the position shown in Fig. 20 and prevent the further escape of brake-cylinder air. The brake can be released by placing the automatic brake valve in release position for an instant, thereby forcing the triple pistons to release position and exhausting the air that is holding the double check-valves over. With sufficient excess pressure, an improperly working feed-valve will produce the same effect, and the same procedure should be followed to get the brake off until the feed-valve can be repaired. In switching service, temporary relief can be obtained by closing the double-heading cock and draining the auxiliary reservoir on the engine and tender.

89. When using the automatic brake, keep the straight-air brake valve in release position, and when using or releasing the straight-air brake, keep the automatic brake valve in running position, to avoid driver and tender brakes sticking.

Automatic brakes must not be used while the straight-air brake is applied. First release the straight-air brake.

The straight-air reducing valve should be kept adjusted at 45 pounds, and the driver and tender safety valves at 53 pounds. Where a full application of the straight-air brake causes either or both safety valves to operate, it indicates too high adjustment of the reducing valve or too low adjustment of safety valves. Have them tested and adjusted.

The straight-air brake valve should be left in application position, to insure against the engine moving, when oiling or taking water. When standing on moderate grades, the train can be held by the straight-air brake and the automatic brakes fully recharged, thus avoiding starting trains on grades with the brakes undercharged.

S-3-A STRAIGHT-AIR BRAKE VALVE

90. Purpose.—The S-3-A straight-air brake valve performs the same functions as the S-3 brake valve and in addition provides a means of releasing the driver brake after that has been applied by the automatic brake valve. When this type of valve is used, it is therefore not necessary to use cock *D* and its piping as with the S-3 brake valve.

91. Construction.—Fig. 27 shows the construction of the S-3-A brake valve and the additional parts necessary for the release of the driver brake. The additional parts consist of a check-valve case *25*, containing a double-seated check-valve *23*, and a pipe, which is connected to the check-valve case at *a* and leads to the automatic side of the double check-valve on the engine. The brake valve also has a running position. The check-valve case is screwed into the opening made by removing cap nut *U*, Fig. 22. The check-valve *23*, Fig. 27, has vertical grooves *d* cut in its circumference. The upper and lower faces of valve *23* make an air-tight joint at *b* and *c* when the valve is in its upper or lower positions, but between these positions air can pass the valve through grooves *d*. The construction of the brake valve in other respects is similar to the S-3 valve already described, the pipe to the straight-air side of the double check-valve being made at *Y*, and the exhaust port being at *Z*.

92. Operation.—The S-3-A brake valve operates the same as the S-3 valve in application and lap position, except that the brake-cylinder pressure is on top of valve *23* and forces it to its lower seat *c*, thus preventing the air from escaping through pipe *a* to the triple-valve exhaust port. Either running or release position can be used to release the driver brake after a straight-air application, although the running position is generally used. Release position is used to release the brake after it has been applied with an automatic application. If after a straight-air application, the brake-valve handle is placed in either running or release position, the projection on shaft *2* engages the valve stem *11* of exhaust valve *9*, unseats this valve, and permits the air from the brake cylinders to pass from the pipe *Y* to the exhaust at *Z*.

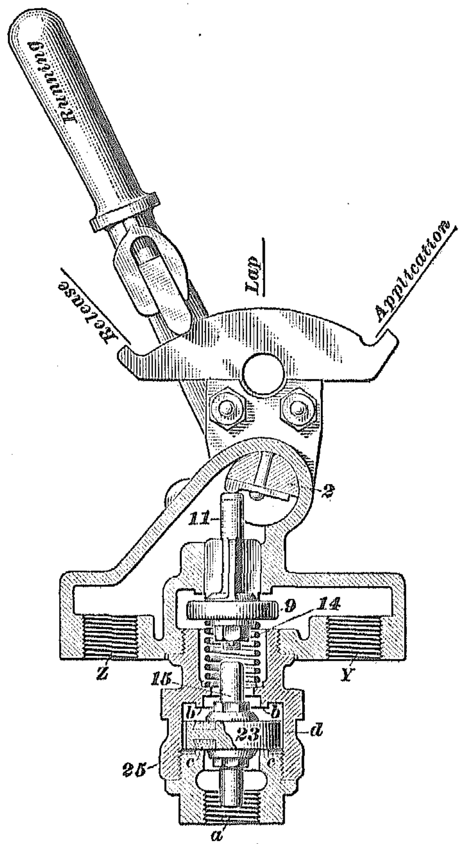


FIG. 27

When the brake has been applied by the automatic brake valve, auxiliary-reservoir air passing to the driver-brake cylinders also passes through the pipe that is connected at *a* and forces valve *23* upwards, the upper face of the valve then seating against its upper seat at *b*. Brake-cylinder air is thus prevented from escaping at *Z* by way of valve *9*, which is unseated in running position of the straight-air brake valve. If it is

now desired to release the driver brake, the brake-valve handle is moved to release position. Valve *9* is forced downwards farther than in running position, and its lower stem *14* engages the upper stem *15* of valve *23*, thus forcing the valve away from its seat. The air in pipe *a* and therefore in the brake cylinders can then pass around valve *23*, through grooves *d* by valve *9*, and escapes at the exhaust port *Z*. The brake-valve handle must be returned to running position, as, if it is left in release position, the driver brake cannot be applied by the automatic brake valve.

HOSE AND COUPLINGS

93. Fig. 28 (*a*) shows an air hose and coupling complete, consisting of a hose *a*, and a hose coupling *b* that includes a hose-coupling gasket *2* and a hose nipple *c*. An air hose is connected to the brake pipe at each end of a car, the purpose being to make, when coupled, a flexible and air-tight connection between the brake pipes on adjacent cars.

The hose nipple screws into the angle cock on the brake pipe, and the hose coupling, when coupled to the hose coupling on the next car, is designed to make a practically air-tight connection between the two hose. The hose is secured to the hose coupling and hose nipple by hose clamps *d*, and hose-clamp bolts and nuts.

94. Coupling the Hose.—Views (*b*), (*c*), and (*d*), Fig. 28, show the operation of coupling two hose together. In view (*b*) are shown the two couplings being raised to position to begin the coupling, in view (*c*) the coupling being started, and in view (*d*) the coupling completed.

Placing the couplings together as shown in view (*b*) brings the hose-coupling gaskets *2* in each coupling squarely over each other and also brings lugs *e* on each coupling on the inside of lugs *f*. The two couplings are then pressed firmly together endwise, and are then rotated by pulling downwards, until the lugs *e* strike the stop pins *g*, view (*d*), the coupling movement being assisted by the tendency of the hose to assume their normal positions. Failure to couple the hose properly distorts the

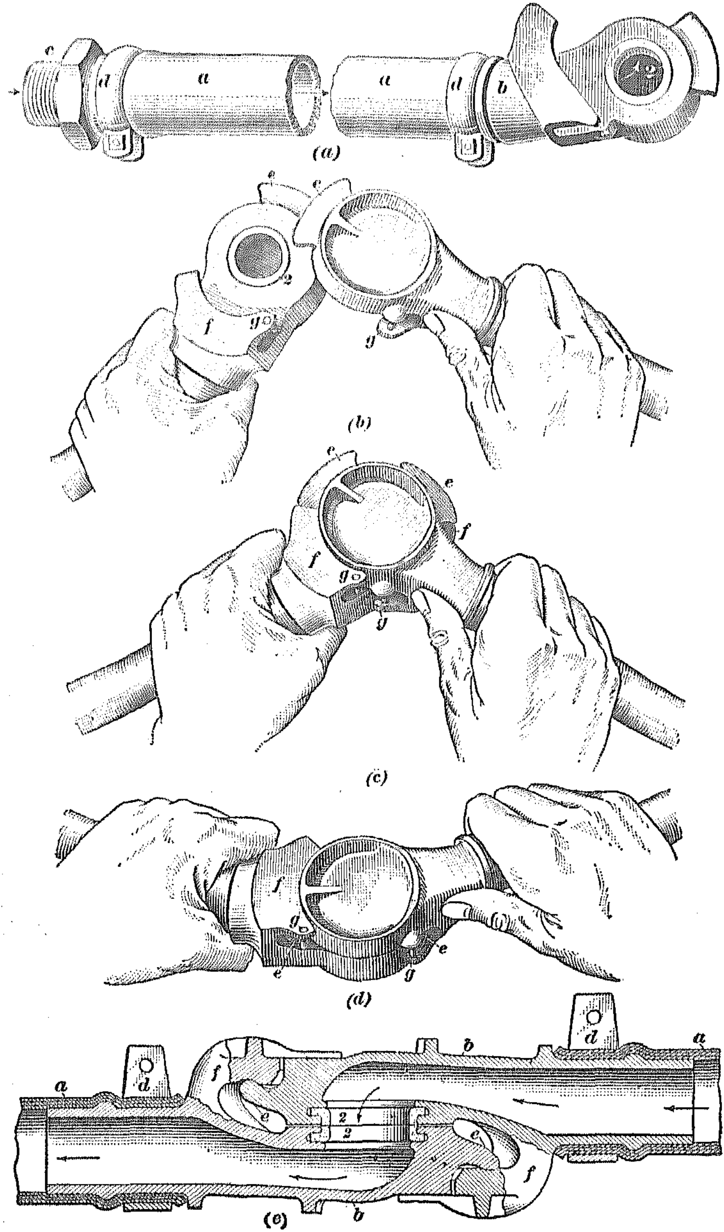


FIG. 28

coupling gaskets and forces their flanges out of the grooves, thus causing leakage.

95. The outer ends of lugs *f* flare outwards slightly and the outer ends of lugs *e* inwards, the effect being to draw the two couplings together in a wedging movement when the coupling is being made, thereby bringing the face of gasket *2* in each coupling firmly against each other and thus preventing leakage. View (*e*) is a sectional view of two hose couplings connected. The hose-coupling gaskets *2* fit in grooves in each of the couplings. This view also shows how the outer faces of lugs *e* on the couplings bear against the inner faces of lugs *f*.

96. Replacing Hose and Gaskets.—In replacing defective air hose, care should be taken to have the faces of the couplings come together without twisting the hose. When a new hose-coupling gasket is applied, the groove in the coupling should be well cleaned, and the flanged part of the gasket then placed in the groove and applied evenly all the way around. A cleaning tool is furnished for applying new gaskets, the point being used to clean the groove and the handle to apply the gasket properly in the groove.

97. Air hose should always be uncoupled by hand; for leaving them coupled to be pulled apart by the separation of the cars springs the lugs on the couplings and causes leakage at the gaskets, as they are not then pressed firmly together when the hose are coupled. Couplings should not be hammered together to stop leakage, as this will prevent them from separating at this point in the event of a break-in-two, the result being that either the hose or brake pipe will be torn off.

ANGLE COCK

98. In Fig. 29 (*a*) is shown an exterior view of an angle cock with a self-locking handle, and in (*b*) is a sectional view. This type of angle cock is standard for all air-brake equipments. The handle is locked in both open and closed positions, and therefore cannot be accidentally moved.

99. Names of Parts.—In view (*b*), Fig. 29, *2* is the body; *3*, the key; *4*, the handle; *5*, the spring; and *6*, the cap. The key is tapered and the spring *5* holds the key tight in its bush. A slot in the key registers with a slot in the bush when the angle cock is open, as shown, but when closed the two slots do not register and the passage of air is prevented.

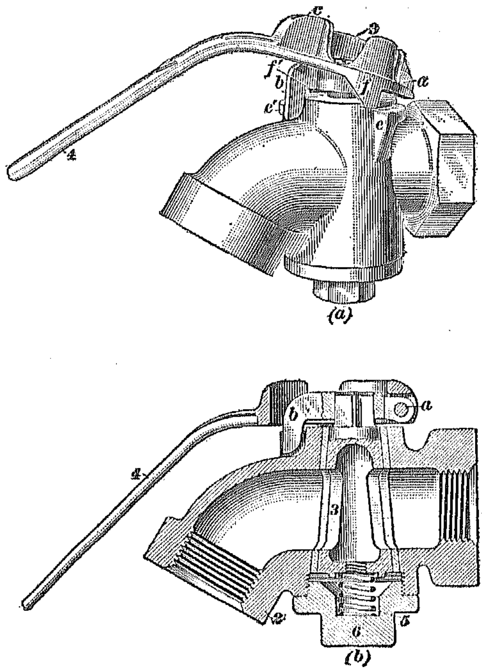


FIG. 29

In view (*a*) the key *3* that controls the passage of air through the angle cock is operated by a handle *4*, the handle being attached to the key by a pin *a*. The movement of the handle is imparted to the key by means of a lug *b* (on the key) that operates within a slot *c* in the handle. Lugs *e* and *e′* on the body act as stops for lug *b* when the key is rotated by the handle. Lugs *e* and *e′* also act in combination with two lugs *f* and *f′* on each side of the handle *4* to hold the handle locked.

100. Operation.—In view (*a*), Fig. 29, the handle is shown raised and is now in a position to move the key *3*, as

lug *f* clears lug *e;* but when the handle is lowered, lug *f* engages lug *e*, thereby preventing the handle from being moved to closed position. Raising the handle and turning it crosswise of the pipe rotates the key *3* and brings lug *b* against lug *e*. This allows the handle to fall, and causes lug *f′*, which is similar in form to lug *f*, to fall in front of lug *e′*. The handle is thereby locked in closed position.